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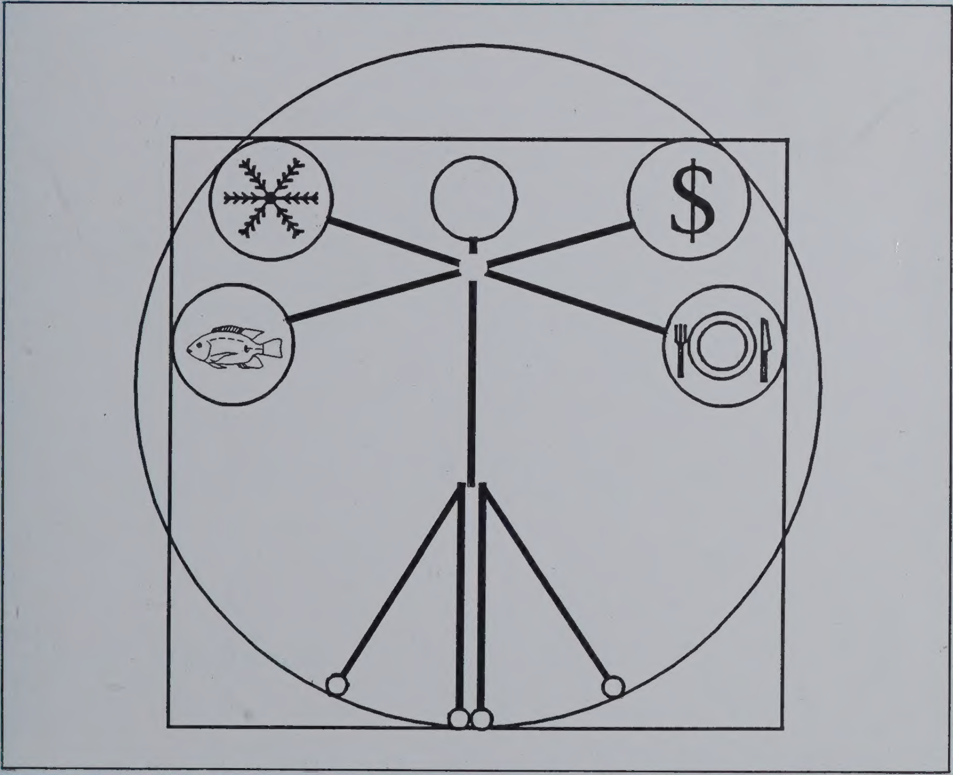

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National Marine Fisheries Service
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by

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PREPARATION OF THIS DOCUMENT

This manual is basically the result of the efforts to cover the training needs of fish technologists, particularly in developing countries, in the area of micro-economics applied to the fishery industry. The authors started to be involved in the project to produce a unitary technical manual in this area many years ago, when they were all employed at the Fish Technology Research Centre (CITEP) of Mar del Plata, Argentina. They had found that extension work was practically impossible, regardless of the scale of the fishery industry, if proper economic analysis did not accompany the proposed technology. They also realized that most of the technical professionals (engineers, veterinarians, food technologists) in contact with the fishery industry lacked the proper grounding. Moreover, they discovered that many managers and owners of small and medium level industries were not fully conversant with the tools that could help them to run and evolve their companies.

Later, one of the authors (HML) came to be in charge of the FAO/DANIDA Training Project on Fish Technology and Quality Control (GCP/INT/391/DEN), and found a similar situation with many fish technologists, managers and owners in developing countries. It was also observed that in practice this prevented extension (communication) of even simple technologies such as icing, and therefore hindered development.

The authors (AZ and MAP) have applied the approach proposed here to real cases while carrying out consultancies for the fishery industry and banks in Argentina. The approach has been also successfully evaluated against actual fishery industry situations in various developing countries during the development of training activities of project GCP/INT/391/DEN. Several fishery investments projects where FAO has been involved have been also re-analyzed. Successive versions of this manual, or parts of it, have been utilized as lecture notes in more than twenty different training activities in Africa, Asia, Latin America and the Caribbean. This has proved particularly useful in testing the data and methods proposed under different conditions, from artisanal to industrial levels.

The preparation and publication of this document has been financed by the FAO/DANIDA Training Project on Fish Technology and Quality Assurance GCP/INT/609/DEN (formerly GCP/INT/391/DEN). However, FAO decided to publish it as a Fisheries Technical Paper in order to make it available to a wide audience.

The bibliographical references have been presented as submitted by the authors.

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ABSTRACT

This manual analyses the micro-economics of the fish processing industry. It is mainly aimed at fish technologists, extensionists and managers and owners of small-and medium-scale fish industries particularly in developing countries. The main topics discussed are: Production Engineering, Capital Investment Costs, Production Costs, Micro-economic Analysis of Production, Analysis and Selection of Alternatives, Profitability and Quality and Safety Economics. Procedures and techniques included in the manual can be applied to analyse: the feasibility of new investments, the performance of existing fish processing plants and process modifications. It contains a large number of worked-out examples and case studies. Although the manual adopts a classical approach, it shows how this can be integrated with the proper management of resources and the production of safe and quality fish and fishery products. Aspects, such as the need of proper management of resources like energy and water, and the impact of environmental concerns are also discussed. The primary purpose of this document is to serve as a training manual; however, it is expected that it could contribute to the self-sustainability of the fishery industry in developing countries at a time that development can hardly be sought in the expansion of fish catches, but in the wise management of all existing resources.

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The authors are indebted to many colleagues and to FAO/DANIDA workshop participants throughout the world, who have given constructive criticism and useful comments on early drafts.

Much appreciated was the assistance of the fishing industry associations (Fresh and Frozen Fish, Fish Canning and Fishing Boat Owners) of Mar del Plata (Argentina), who facilitated a thorough measurement and experimental checking of most of the parameters involved in the methods and models presented; and to fishery industry people from many countries around the world, in particular Denmark, who provided useful information and comments.

Special thanks are due to Mr I. Kollavik-Jensen and Ms. L. Gadaleta for their tireless effort in reading proofs of manuscripts, and providing relevant comments;
Ms. Dawn Spencer-Di Napoli improved the English and Ms. J. Browning typed the final text.

While the contributions of all those mentioned above certainly helped to make this manual more useful and easily readable, inadvertent errors and the weakness that some sections or chapters may present are the responsibility only of the authors.

Finally, the authors (AZ and MAP) want to acknowledge the financial support received from the National Council of Scientific and Technical Research of Argentina (CONICET), during the preparation of this document.

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INTRODUCTION

What is Economic Engineering?

Economic engineering is a specialized field, incorporating a knowledge of engineering and basic micro-economics. Its main function is to facilitate decision-making based on the economic comparison of different technological alternatives for investment. Its techniques, ranging from use of standard spreadsheets for evaluating cash flow to more elaborate methods such as risk analysis, can be applied to personal investments and to industrial enterprises.

The authors followed the approach of many Food Technology and Chemical Engineering Schools of American Universities, that normally offer one or more courses, usually at MSc level, where micro-economic analysis of food or chemical industries is included. They freely adapted this approach to the characteristics and perceived needs of the fishery industry, and particularly of developing countries.

In many developing countries there are real difficulties with practical understanding and application of key concepts like depreciation, financing and cost formation, particularly when dealing with small-and medium-scale fishery industry, including artisanal fish processing. This situation certainly hinders the possibility of self-sustained activities, very often prevents the introduction of necessary technical improvements and contributes to the wastage of human and financial resources. Certainly, fish technologists working in production, extension or assisting in the development of investment projects, should be prepared to assist.

Fish technologists involved in designing and operating fish plants are frequently faced with the following questions:

- Which design, among the various investment alternatives, should be selected?
- Should the equipment currently being used be replaced by new equipment? And if so, how soon?
- Are the expected benefits sufficient to justify investment?
- Is a conservative and more secure project preferable to a more risky one that could bring greater benefits?

These questions have elements in common: 1) each involves a choice between technical options; and 2) all involve economic considerations. Other less evident factors are the need for sufficient data, and awareness of the technological restrictions in order to define the problem, identify possible solutions and determine the best. Consequently, it must be ensured that the design, operation, and economic evaluation form a cohesive whole.

Finally, the term "investment" is used in this manual in a broad context; it can be aimed at a large plant, a processing line, a change in a processing line, development of a new product, the decision between two or more different technologies to obtain the same product, at the analysis of a single operation (e.g., icing fish), the introduction of a new quality control system, etc. At the same time, the term "investment" is intended independently of the level of investment and the source of financing.

Why Apply Economic Engineering to the Fishery Industry?

The fishery industry is involved in many activities covering all aspects of the business spectrum: buying inputs, applying for loans, paying for labour, planning for the future and making profits. These exist throughout a fisheries system: in capture, processing and marketing. Also, as in any industry, artisanal or industrial fisheries have characteristics which must be identified in order to better understand the fishery industry overall.

A business is a project which has different objectives. In principle, the objectives can be divided between those which must be fulfilled to assure complete self-sustainability, and those which are important, but not essential to such an end.

An essential objective, from an economic viewpoint, is to be economically self-sustained, i.e., to pay back the resources invested and generate a profit within a reasonable time. Accomplishment of this objective is a necessary condition because without it the project will not be viable, and will fail when the initial capital finishes, or when the subsidies cease. Most of the manual is devoted to the analysis of this objective. However, it is not forgotten that in the case of the fishery industry there are other necessary conditions for self-sustainability.

The most obvious is the need for a rational management of fishery and environmental resources. The relationship between the whole economics of a fishery and the management of the resources linked to it, is reviewed in section 5.5. Fish as food, the ultimate objective of the fishery industry, should also be safe and of the quality required by consumers and public regulations. This is also a necessary condition, interacting with the economics of a company; and as such is analysed in Chapter 8.

Neither the economic soundness of a project nor its actual operation is in itself a sufficient condition for investment; they are, however, both necessary *(sine qua non)* conditions. In this context, economic engineering applied to the fishery industry appears to be a suitable contribution to assist the management and sustainability of the sector, particularly in developing countries.

To what Type of Fisheries can Economic Engineering be Applied?

The world's fisheries have a common characteristic; that is, the existence of industrial fisheries alongside artisanal fisheries. Developing countries, to whom this manual is particularly addressed, have both types of fisheries, with a mix and a relative importance, that should be studied case-by-case, and in some countries even region-by-region.

Based on general historical considerations (e.g., in Europe), fisheries development means an evolution from the subsistence to artisanal stage, then to the small-scale and finally to the semi-industrial and industrial stages. This development usually implies external investment and/or reinvestment and a redistribution of human resources (for instance, in the development of the industrial fisheries in Uruguay during the 1970s).

Development also means avoiding obsolescence, and keeping abreast of new technologies, procedures, market requirements, etc. A characteristic of the dynamics of sustainable development is the need for an endless chain of techno-economic decisions. In both developed and developing countries static fisheries systems are found (e.g., the "tonnara" in Italy), unchanged and stable for centuries. These issues are not discussed here since many other factors (e.g., culture, politics, employment, tourism) may contribute to them.

Whereas industrial fisheries could be identified according to the technologies utilized and investment, there is no universally-accepted definition of small-scale fisheries. Existing fisheries are classified into several groups: artisanal and industrial or commercial; small and large scale; operating range of vessels (near or far from shore); or types of nets used (Thailand), size of vessels (Indonesia, Philippines) or distance from shore (Hong Kong) or a combination of the three (Malaysia). What one country considers large-scale, is often regarded as small-scale by another. It is generally accepted though, that large-scale fisheries operate in deep waters, whereas small-scale fisheries have limited catch capacity, operate in an adverse socio-economic environment, are confined to a narrow strip of sea and land, and are utilized by a community which has limited options and is dependent on local resources (Panayotou, 1982).

This manual does not make a separate and comparative study of small-scale and industrial fisheries, but attempts to present a consolidated picture of the actual situation.

A global analysis is made of the most important factors in fishery production and processing structures and in the design of associated operations and processes, with particular emphasis on the economic aspects of the fishery industry. Investments in capital goods, the costs of production and their profitability are considered qualitatively and quantitatively. Also, a brief micro-economic analysis of production is included. This analysis, which enables fishery products to be produced with maximum efficiency, can be applied to single production lines, plants or the evaluation of an entire national sector.

Fish consumers are changing attitudes both in developed and developing countries. This has many implications for the fishery industry, in particular the need to compete in markets that require safer seafoods of increasing quality, without great changes in relative prices. A close study and monitoring of safety and quality costs are needed in a way which simple accountancy cannot provide. This type of study and monitoring implies a close interlink between technology and economics. The aim is to achieve safer and better fishery products at lower cost through changes in processes, management, storage and distribution.

What are the Limitations of the Approach Proposed?

Analysis of micro-economics depends on models (and/or ideologies) and is therefore limited in the way that models are limited, or in the way conditions for application of such models do not apply to a given situation. Policies can differ even in countries that refer to the same nominal political system, and thus affect the economic analysis in different ways (e.g., how depreciation is allowed, or how taxation is applied). An in-depth discussion of all the possibilities is outside the scope of this manual, although some aspects are discussed.

As fish is a natural resource and fisheries are deeply linked to the environment, readers could expect an "alternative" micro-economics approach. The authors support the view of Pearce and Turner (1990) that many, but not all, of the environmental and natural resource concerns can be treated and analysed by applying a conventional approach, rather than developing "alternative" micro-economics. Such an approach has the advantage, at least initially, that it will be better understood by public administrators and the industry. Probably, in the near future, most of the quality-of-life and environmental considerations could be incorporated into the micro-economic analysis as costs of non-conformance; this means costs incurred because a specified condition of raw material, product or processing cannot be achieved. Examples of this possible approach are discussed in Chapter 8.

From a strict economic viewpoint, there is no conceptual or theoretical development (e.g., an "existence theorem") that can assure us "that whatever economy we devise will be sustainable ecologically. The only way to be sure of this sustainability is to ensure that economic models have sustainability conditions built into them" (Pearce and Turner, 1990).

In fisheries it is very easy to fall into the discussion "practice vs. theory". As the late Gordon Eddie (1983) wrote, referring to the controversial objectives in capture: "Underlying such situations is the uncomfortable fact that, where fishing is for profit rather than for food, the objectives of the fisherman are not necessarily quite the same, at least in the short term, as the objectives of those who discuss fisheries management in terms of biomass, yield and catch".

Without dismissing the importance of practical knowledge, it is clear that in most fisheries it is not enough to keep business going on a short-term sustainable basis. The main reason is that the horizons of "mid" and "long" terms are nearer than they used to be, as can be seen from the brief historical account presented in section 1.1. As Dale and Plunkett (1992) comment, proposed quality improvements without clear reference to short-term efficacy, may be taken as a blind act of faith, and opposed to the current mentality of western businessmen and managers.

The authors are aware that the conventional approach used may give the false impression that changes in the fishery industry happen gradually and smoothly. This means in a situation that can be reversed by proper management if proved wrong. Unfortunately, this is not always the case, as can be seen from the recent collapse of shrimp farming in China or overfishing in the Grand Banks. Fishery fate is linked to a biological resource and to consumer preference, changes of an output variable (e.g., landings, profit) may vary gradually against a control variable (e.g., fishing effort), but only up to a point. Once this point has been reached, changes in the output variable are completely disproportionate to or insensible of the changes in the control variable. This situation, relatively common in the physical and biological world, could be interpreted through the "catastrophe" model (or theory) (e.g., Woodcock and Davies, 1982), and seems to apply to fish stock collapses both in the wild and in aquaculture, but it may also be used, for instance, to analyse fish market changes due to perceived lack of safety or quality. The authors have avoided, as much as possible, pure theoretical considerations.

The space devoted to optimization techniques (Chapter 6) may seem relatively limited. Importance of optimization techniques is growing, and will be an essential tool in the near future for most of the fishery industry, but the authors considered that the detailed description of techniques, development of examples and numerical models (optimization depends on the formulation of an objective function) would exceed the scope of the manual. In American universities optimization is usually discussed in a separate course.

Finally, it should be recognized that to run a business means to take risks, since uncertainties cannot be avoided. The manual can help to reduce the number of "uncertainties", particularly those that can be tackled in a rational way. Unfortunately, no book exists that can explain how to eliminate them or how to become a successful entrepreneur.

How to Use this Manual?

This publication is intended primarily as a training manual and not as a handbook: it is hoped that interested readers may find it useful. A course, incorporating all this manual, would require about 40-45 hours of lectures, including 10-12 hours of general applied seminars, plus around 45 hours of guided practical work (that in formal courses could be homework). Shorter courses could be organized depending on the previous knowledge of the target group. Some chapters, in particular 5 to 8, could eventually be used separately. For instance chapter 8 could be the basis for a seminar on quality and safety costs.

Readers in general should have a good knowledge of fish technology and basic algebra. Previous knowledge of financial mathematics would be helpful, although not strictly necessary. The mathematics level has been kept to a minimum, except (e.g., in section 7.9 when discussing the influence of inflation on profitability) where there was no alternative to present the topic more simply. The manual could thus be directly used in Fishery Schools (Diploma Courses) as they exist in some African, Asiatic and Caribbean Countries, or in Technical High Schools and Vocational Courses (at tertiary level) in Latin America. It could also serve as a basis for a university level course, although here a more formal treatment would be required (e.g., the inclusion of calculus and statistics and use of appropriate computer software).

A large number of tables and information can be used directly in calculations. There are data that can be updated easily for actual calculations (e.g., cost of machinery, energy and water, taxes, salaries) and data that should be checked in case of doubt (e.g., yield of a given species of fish, productivity of workers sitting or standing in different positions). During the workshops in which this document has been used, the first step of practical work was to find out the actual values of parameters involved in calculations. This is an excellent practical exercise in itself, and can generate information about the actual situation of a country and its fisheries.

People in developed countries (and in a few developing countries) can now have access, through Internet, to computer databases (e.g., national bureau of statistics) in which they can find easily and cheaply some of the information necessary for calculations (e.g., average level of salaries, construction indexes, series of exchange currency rates). Unfortunately, those databases are not available to all, and it is not possible to have information on all countries, in particular developing countries.

Advice to fish technologists in developing countries is to construct little by little their own "database". A small computer would be useful but not essential. A notebook with an index (e.g., following more or less the chapters of this manual) will suffice for most practical purposes (provided the level of information does not become too great). Information could come from personal research (e.g., asking for costs, number of people employed in a plant, actual salaries paid, yield of a given species), from information published officially (e.g., statistics) or through books, journals (e.g., exchange rates) and magazines.

Finally, fish technologists will become aware that there is still need of applied research in a number of subjects, for instance in the areas of energy and water consumption.

1. PAST, PRESENT AND POSSIBLE FUTURE OF THE FISHERY INDUSTRY

For those outside the fishery industry, and sometimes even for those conversant with it, the endeavour of fish production, utilization and marketing often appears rather strange, difficult to understand and generally obscure. This is partly due to the intrinsic complexity of fisheries that embraces the latest technology to obtain food from the wild, to the use of satellites, electronic equipment, robots and bioengineering. It is also partly due to the large number of fish species marketed (e.g., it is reported that in the US market more than 700 different commercial species can be found), which makes fish a very different protein source from, for instance, meat and chicken.

Part of the complexity stems from the large number of products available (e.g., a fish market is more segmented than meat or poultry markets, and segmented in a different way), processes and their variations, and catching methods ranging from beach nets and canoes to high-tech factory trawlers. The complexity at local, regional and international levels is also related to deep historical and cultural reasons, without which consumption habits (and hence market demand), *ad hoc* laws and regulations, fishermen's behaviour, political moves and the commoner's position regarding fish and fisheries are very difficult to understand. Whereas in some industries (e.g., electronics) history and culture are practically irrelevant to their economics, in fisheries they usually play an important part although very often overlooked or taken for granted.

Although an in-depth review of this complexity is outside the scope of this manual, it was decided to include a brief description of the past, present and probable future of the fishery industry. This chapter should be read mainly as a caution in that the methods of economic engineering to be analysed in the rest of the manual, cannot usually be applied instantly and require a consistent knowledge of the past and present of the specific fishery industry and intended markets, as well as an educated guess about the future.

1.1 Brief on the Historical Development of Fish Production and Utilization

Since prehistory, fish has been caught and eaten first by hominids *(Australopithicus* and *Homo erectus)* and then by men (*Homo sapiens*) (Stewart, 1994). There is enough archaeological evidence that men were already catching fish in the Lower Palaeolithic Age, more than 100 000 years ago, and the earliest record of fish as food for *Homo sapiens* is 380 000 years old. In more recent prehistoric times, there is plenty of evidence that European populations habitually utilized fish as food, salmon being one of the most widely consumed fish, and some Amerindian and African populations were known shellfish gatherers (Toussaint-Samat, 1992).

Fish was appreciated by ancient Egyptian and Chinese civilizations. The first recorded recipe (a fish salad based on marinated and spiced carp) is from ancient China dated 1300 B.C. The ancient Romans' passion for fish is very well known; the highest recorded price for an auctioned fish (two live red mullets) ever paid (20 000 sestertii, about US$ 24 000 today) has not yet been surpassed (Toussaint-Samat, 1992). Fresh fish has always been preferred. The Chinese have been trading live fish for over 3 000 years. In the Roman Empire, the best quality fish was also kept, transported and sold live (in particular eels and lampreys). There is evidence that the Chinese utilized natural ice to keep fresh fish about 1000 B.C.. Ancient Romans also used ice mixed with seaweed to keep fresh fish (they transported ice from the mountains near Rome).

Fish drying, smoking and salting were used to cure fish from very ancient times in different cultures. Fish salting and fish fermentation were already a flourishing integrated industry almost in contemporary terms (capture, farming, processing, packaging, transport and distribution) in the Roman Empire about 100 B.C. (McCann, 1988). Curing techniques have been revised and refined several times during the history of mankind and are still widely used. It is reported that salting herring onboard was introduced by the Dutch in the fourteenth century. This allowed longer fishing trips and reduced post-harvest losses, improving the production and economics of salted herring. Likewise, in the twentieth century, freezing trawlers and factory vessels were introduced to freeze and process fish onboard.

Fish farming became an affirmed technology in China between 2000 and 1500 B.C. and has never ceased to be a source of food. The first treaty on carp culture was written around 475 B.C. by a Chinese named Fan Li (Toussaint-Samat, 1992). This contains useful advice on design, construction, harvesting and economic management of fish ponds (Kreuzer, 1974).

Aquaculture in Italy can be traced back to the fifth-sixth century B.C., when the Etruscans developed it in coastal lagoons of the Tyrrhenian Sea (Mediterranean). Near the Port of Cosa, they performed impressive engineering works, cutting a channel in the rock (tagliata di Ansedonia) for the hydraulic management of a lagoon of between 500 and 1000 ha (Ardizzone *et al.*, 1988). Later, the ancient Romans, as demonstrated by archaeological studies (McCann, 1988) developed in the same place, about 100 B.C., a sophisticated brackishwater aquaculture complex, integrating it with fish processing, packaging, and shipment of final products to many places in the Mediterranean basin. This complex also included seasonal coastal fishing of species like mackerel and tuna. The remainder of the Etruscan coastal lagoon of Cosa, the Burano lagoon (140 ha), is still exploited. The inhabitants of Cosa incorporated at a later stage the exploitation of the Orbetello lagoon (2 700 ha), one of the early examples of efficient fisheries management of coastal lagoons (Ardizzone *et al.*, 1988). The aquaculture activities in this area have been and still are integrated with marine fisheries (Porto Santo Stefano). The case of Cosa, as many other examples that can be found, particularly in the Mediterranean, China and Japan, testimony the tight relationship between self-sustained fishery activities, social and cultural aspects and environment.

There is also enough historical evidence that aquaculture in Europe continued to be an important source of protein for almost a thousand years after the collapse of the Roman Empire. Fish production in Europe was always a mixture of cultured and wild fish from marine and inland water sources (Montanari, 1993). A traveller at the beginning of the eighteenth century observed that fish consumption in Poland consisted of salted herring (imported from the Netherlands and Scotland), salted-dried cod, marine fish from the Baltic Sea (coastal populations) and farmed fish in the hinterland (Salmon, 1735).

Fish consumption has been affected positively and negatively by religions, taboos, political decisions and beliefs throughout history, which in turn have affected fish production and marketing. Fish consumption during the Middle Ages in Europe was promoted by the Catholic Church which ordered 166 days of fasting a year (including 40 days of strict fasting for Lent) during which fish could be eaten. This situation was usually reinforced by rulers; for instance, Charlemagne ordered that all his farms have fish ponds. Alternatively, the Reformation in England (involving changes in fasting) reduced the number of fishing vessels, severely affected freshwater fisheries (Montanari, 1993), and nearly abolished aquaculture

(Kreuzer, 1974). As discussed later, this situation was to change again in the seventeenth century with the development of the herring fishery.

The importance of aquaculture in Europe declined for many reasons which varied from country to country; aquaculture collapsed in Germany during the Thirty Years' War (1618-38) and did not recover until the end of the nineteenth century (Kreuzer, 1974). The development of marine fisheries during the nineteenth and twentieth centuries reduced even further the relative contribution of aquaculture; a change mainly due to the large yield of marine captures in respect of investment, and the worldwide development of markets for certain types of salted fish (that allowed for storage and transport).

The importance of marine fishery captures, particularly cod and herring, increased in Europe from the thirteenth and fourteenth centuries, particularly in the northern countries. The fourteenth century was a period of famine in Europe and probably obliged coastal populations to increase the pressure on marine fishery resources. As Montanari (1993) points out the plague that devastated Europe between 1347 and 1351 affected the coastal populations that consumed fish as a source of protein and lipids (energy) far less than the inland populations which were stressed and prone to illness due to starvation.

During the thirteenth century, herring shifted its spawning migrations from the North Sea to the Baltic Sea. It gave the Hanseatic League the possibility of developing the largest fishery industry of the time, replacing Denmark which had previously exploited this resource (not without war). This situation lasted until the sixteenth century when herring returned to spawn again in the North Sea and this time the Netherlands grasped the opportunity to develop as a major fishing country (Kreuzer, 1974).

This return of the herring to the North Sea also triggered off the development of the Scottish herring fishery during the seventeenth century. By the second half of the seventeenth century salted fish was one of the main British exports to Europe. In the period January-March 1665 at the port of Leghorn [Livorno] (then Great Duchy of Tuscany) 9 020 barrels of salted herring were unloaded (including 220 of "white" salted herring), 345 barrels of salted salmon and 500 small barrels of salted pressed sardine (*saracche or salachi*) transported from Britain, and comprising almost the total cargo of eleven vessels (Cipolla, 1992). It could be presumed that the access to markets for salted herring was a main cause for friction between Britain and the Netherlands at that time.

Fishing rights were very often part of peace treaties between European countries. The Treaty of Utrech (1713), although recognizing, in principle, to Spanish fishermen (mainly Basques), the right to fish for cod and whales off Newfoundland (the Basques had been fishing there since before 1550), in practice it deprived them such a right. This forced the Spaniards to look for alternatives, for instance, to increase fishing and salting sardine off Galicia and to increase fishery imports. As one of the measures to tackle the lack of fish the Spanish King Charles IV founded, in 1789, a fishing company based in Puerto Deseado (Patagonia, now Argentina) with the purpose of fishing and salting. The Spaniards returned to fish off Newfoundland only in 1921 (Lopez Capont, 1986). The development of this conflict is still making news (1995).

By the early nineteenth century, new methods were needed to extend the shelf-life of fish and fishery products. Canning of fish and meat were invented by the Frenchman, Appert (procedure published 1810) as a means of supplying food to Napoleon's army.

The effect of low temperature on the keeping time and quality of fresh fish was known throughout the ages. "Weather freezing" is a method applied since time immemorial by Eskimos; it consists in leaving fish outside in windy conditions of subfreezing temperatures and was probably the start of the modern fish-freezing industry. There are records that indicate that "weather freezing" was carried out in the region of the Great Lakes (USA and Canada) early in the nineteenth century and the method was still applied there in the 1960s (Tressler *et al.*, 1968). It was not until the development of mechanical refrigeration in the nineteenth century that ice and cold facilities became readily available. The French engineer, F. Carré, constructed the first ice-block machine, presented at the Great Exhibition of London in 1859.

In 1877 the first cargo of mutton, using mechanical refrigeration, was transported from France to Buenos Aires (Argentina) onboard the vessel "Le Frigorifique", mainly to demonstrate that intercontinental transport of frozen foods was feasible. The Argentineans, with the assistance of Carré, fitted out a second vessel "Paraguay" and started to transport frozen meat to Europe (Toussaint-Samat, 1992).

The Americans were the first to realize the potential market possibilities of frozen fish, and by 1865 they started to freeze fish by putting it in pans surrounded by ice and salt. Around 1880 ammonia refrigeration machines had begun to be utilized and by the end of the nineteenth century fish freezing was an important industry in the USA which had started to export frozen salmon to Europe. At that time, fish was being frozen in Europe, but in smaller quantities than in the USA (Tressler *et al.*, 1968). The initial quality of frozen fishery products was very poor and the process not well understood (Burgess, 1974). In 1929, an American, Clarence Birdseye, decided to return to the source and find out why Eskimo frozen fish ("weather freezing") was of much better quality than mechanical frozen fish. After spending time with the Eskimos of Labrador, he found that the secret was in the freezing speed; in the USA he developed the first plate and double-belt freezers and initiated the era of "quick freezing" (Toussaint-Samat, 1992).

After the development of the herring and cod fisheries, most of the marine fish consumed in Europe came from sailing boats, like the trawling smacks that drifted downwind with beam trawls. Steam propulsion was introduced in European fishing boats towards the end of the nineteenth century and these mechanized boats replaced sailing fishing boats. Internal combustion engines (Diesel) were introduced in European fisheries at the turn of the nineteenth and twentieth centuries, and completely replaced steam propulsion by the 1960s. After the second world war, fishing boats in Europe started to introduce echo-sounders and echo-ranging to detect fish, and these methods were taken up by industrial fishing fleets all over the world. The first full-scale factory stern trawler, "Fairtry", was constructed in 1953 in Aberdeen, Scotland. It incorporated plate freezers and a combination of plate and blast freezers. Following years of research and development at Torry Research Station, Aberdeen, Scotland, in 1961 commercial vertical plate freezers were installed for the first time onboard the stern trawler "Lord Nelson". Since then there has been a rapid development of fish processing and freezing at sea.

Two important developments during the 1950s and 1960s that enhanced the advantage of mechanization of fishing vessels were the introduction of synthetic fibre in net construction, and the rational design of fishing nets. These developments revamped old fishing methods like trawling, gillnetting and longlining and dramatically increased the catches. However, this development was not conducted *pari passu* with proper management of existing resources and led to significant overexploitation and economic losses being incurred by the world fisheries. These losses have resulted from fleet overcapacity and overinvestment; it is estimated that 46% of the landed value of total world catches were required as return on capital invested in the fleet and this was disproportionately high (FAO, 1995).

The problems of quality and adulteration of food became apparent during the late part nineteenth century, both in Europe and the USA, and the lack of scientific and technical information regarding food, in particular fish, became clear. Problems of food wastage observed during the first world war (Burgess, 1974), and probably the growing problems associated with the food provision to larger urban populations, convinced Governments to create *ad hoc* research and development institutions. The first research institute dealing with fish technology was set up in Norway in 1892.

Freezing and the possibility of developing reliable cold chains lead to the introduction of a large number of products in fish markets in developed countries, particularly after the second world war. Among these were products which made the specific fish species less important and introduced the concept of prepared and semi-prepared products such as fish-fingers, fish-sticks, fish-burgers and fish-pastes.

There are many type of fish-pastes. However, the type that has taken the lead is that originally known as "kamaboko" in Japan. "Kamaboko" and derived products were a traditional fishery product mainly consumed in Japan but also known in China and other Asian countries. It was originally produced artisanally from a few fresh fish; in 1960 the Japanese started to produce kamaboko from frozen kneaded fish flesh from Alaska pollack and mechanized the whole production process. Production of kamaboko and kamaboko-based products escalated in Japan during the 1970s, the technology began to spread and was utilized in the rest of the world. In or around 1975 in Japan, and later in other developed countries, kamaboko began to be utilized for the production of analogs (e.g., king crab legs analog), and opened up the possibility of utilization of the less exploited species and potentially the reduction of the post-harvest losses.

This brief introduction to the historical development of fish production and utilization was included in the manual mainly to give an idea of the medium and long-term dynamic conditions of fisheries. Analysis of long-and medium-term fishery aspects are important in several ways. Apart from the socio-economic considerations (e.g., fish consumption habits and "historical rights" that fishermen very often claim to have), there are other important implications when studying investment and sustainability.

For instance, it is clear that there has been, since the second half of the nineteenth century, a constant reduction in the successive "short-term" horizons of the fishery industry, as a result of the introduction of technical and scientific innovations, and market changes. It is extremely important for developing countries to understand this reduction of the "short-term" fishery industry structure (or technology) in order to achieve self-sustainability and not waste investment. The reduction in the "short-term" horizons makes it necessary to consider the medium and long-term horizons for proper self-sustained development.

1.2 Brief Situation on World Fisheries Resources and Captures

At present the total world catch of fish amounts to about 98 million t (1992) of which 82.5 million t are marine fish and 15.5 million t freshwater fish, including aquaculture. Between 1984 and 1989, landings of marine fish increased from 74 million to 86 million t

(17% increase) while corresponding figures for those in inland waters were 10 million t and 14 million t (38% increase). Following the peak in 1989 marine catches decreased in 1992 by 4% while catches from inland waters continued to grow, increasing by 10% in the same year. In the 1980s, the increase in catches of marine species was due mostly to a notable increase in North and South Pacific catches, which increased by more than 17 million t between 1981 and 1989.

A sustained increase in landings cannot be expected in the future and a decrease in catches could occur in regions which are overfishing. For instance, the North and Central Atlantic regions recorded an almost constant catch in the period 1985-89 (yearly variations less than 1.8% of the average), but catches dropped significantly in 1990 and 1991 (with variations of 5.63 and 6.85% respectively, compared to average catches in 1985-89).

The type of species caught is also very important since it is market-dependent, i.e., it depends on the type of fish that consumers want to buy. Thirteen percent of the total catch is white fish, such as cod, hake, Alaska pollack and haddock. Popular species, e.g., sole in Europe, only represent 1.5% of the total catch. The catch level of sole is more or less steady. However sole-like species of commercial size are discarded as by-catch in some Caribbean shrimp fisheries. They are not appreciated by local consumers, fetch very low prices, and often are even named disrespectfully ("chatarra" in Costa Rica, and "tapaculo" in Cuba). This type of resource may gradually be incorporated into the market, thanks to improved technical knowledge and marketing. Such development is necessary to reduce discarded shrimp by-catch.

The bulk of the world fish catch (some 30%) is made up of small pelagics of relatively small size, with a high lipid content, and which deteriorate quite rapidly. Tuna, bonito, mackerel and snoek, which are especially fatty species but larger and in greater demand commercially, represent 9% of the catch. Pelagic species, especially small-sized ones, are largely affected by environmental factors. This results in catches varying progressively from year to year. In Chile and Peru, the bulk of the small pelagics is used for fishmeal production.

There is sufficient evidence of overfishing throughout the world. In 1993, fishing in the Grand Banks off Canada was closed due to overfishing. Canada recorded landings from the Grand Banks at about 1.15 million t in 1991 alone (O'Riordan, 1994). The Grand Banks, one of the world's richest fishing grounds, have been exploited almost continuously during the last 500 years (or even before if it is true that the Basque fisherman exploited Canadian fishing grounds before the arrival of Columbus in America).

The collapse of the Grand Banks fishery put between 40 000 and 50 000 Canadian fishermen and plant workers out of business, the largest lay-off in Canadian history (Anon., 1995; Swardson, 1995). It also affected local and international fish markets, triggering species substitution both at consumer and industry levels. An example which illustrates this well is that of MacDonalds' fish-burgers, half of which were made out of Grand Banks' cod; today, MacDonalds' has switched to Alaska pollack (Anon., 1994). The case of the Grand Banks will probably become a classic example of overfishing and its consequences; it underlines the fact that the risk of overfishing cannot be ignored.

Overfishing may not be the only cause of the decrease in catches; natural phenomena like "El Niño", environmental changes and long-term biological cycles, play important roles in some regions, affecting average landings significantly. Nevertheless, during the last seven years, landings have shown an overall tendency to stabilize. The fishery industry is thus entering a period where adequate management of fishery resources is unavoidable. Development, except in particular cases and in aquaculture, cannot be based on increased catches.

1.3 Brief Situation of Current World Fish Utilization and Marketing

Seventy-two % of the total fish catch is used for direct human consumption. Almost all the remainder (26%) is used for the production of fishmeal (used for feeding farm animals) and oil. Thirty-one % of all fish for human consumption is eaten fresh and 35% is frozen. Another 16% is processed as cured fish (dried, salted, smoked) and 18 % as canned fish. Thus, 31% is consumed within the first two weeks after capture and 69% preserved in some form or other for later consumption.

Thirty-nine % of the total catch is marketed at the international level, with US$ 37 400 million's worth being traded in 1991. Developing countries play an active part in this trade, and for some of them, Mozambique and Cape Verde for example, fishery exports constitute the main source of non-aid income.

Discards and post-harvest losses of fish are very high. A recent estimate puts total by-catch and discards to between 17.9 and 39.5 million t (average 27 million) per year (Alverson *et al.*, 1994), this means in average about the 30% of the total world catches. Greatest losses are found in the selective fisheries, such as shrimp, where it is not unusual to find a fish by-catch/shrimp ratio of 5:1 or more. Some countries like Cuba make an effort to recover and utilize all the shrimp by-catch, others (e.g., Costa Rica) recover most of the market valuable species. However, in many countries, all fish caught in shrimp nets are discarded.

Other losses occur as a result of flaws in the handling, storage, distribution and processing of fish, and in marketing techniques. The real level of losses is a very controversial issue, in part due to the difficulties in defining losses and measuring them accordingly. Nevertheless, all parties involved recognize that losses exist and must be reduced. The study of losses should be done on a case-by-case basis, and is a key step for improvement. In these circumstances, fish processing will have to focus on reduction of failure costs, in particular reduction of post-harvest losses, clean production (reduction of wastage), and product improvement in terms of quality and convenience to consumers.

1.4 Fish Technology, Economic Engineering and the Future

Fish technology, as a discipline, will continue to play an important role in fishery development. A dramatic change is taking place in the design, operation and management of fishery industries, due to the simultaneous introduction of quality assurance and management concepts, new machinery and electronics, a shift from manual to computerized supervisory control and use of robots, that utilize vision technology. The entire fishery industry will surely change during the next few decades: some of such "twenty-first century fishery industries" already exist for instance in Canada, Denmark and Iceland.

Due to this evolution, the relationship between technology and economics is growing and will become even more important in the future. For instance, the daily monitoring of production economics was introduced in some Scandinavian fishery industries around 1975, computerized production control around 1982, and it is expected that on-line simulation for product management will be introduced in leading fishery industries around 1995 (Valdimarsson, 1992). Such development is impossible without a close relationship between fish technology and economics. This relationship greatly exceeds the classic one existing between both areas and currently utilized in investment studies, since more specific and hence more reliable parameters (e.g., yields, time, temperature, process dynamics) are necessary.

As development aims to increase profits and quality, and simultaneously reduce post-harvest losses and energy consumption, the fishery industry of developing countries will likely have to follow suit in order to avoid being forced out of the markets. There are fishery industries, particulary in Southeast Asia (e.g., Thailand and Malaysia), that have initiated such evolution with apparent success. Evolution of aquaculture and small-scale fisheries will impose additional challenges to fish technologists, all of them linked to economics.

Fish as food is, like any product, dependent on supply and demand, but people, particularly in developing countries, often tend to be more production-(supply) oriented than demand-(marketing) oriented and this can lead to bad investment and consequent losses.

As discussed in the historical review, salted herring and salted dried cod were an unchanged market in Europe for many centuries, until the Americans started to produce frozen fish during the second part of the nineteenth century and ice was widely introduced to chill fish. Since then, several changes due to the introduction of new technologies (including management) or simply market developments have followed, and the European fish market has today very little in common with that of the mid-nineteenth century. Despite the visible and relatively quick changes in the markets, those in the fishery industry of developing countries (and sometimes in developed countries) very often tend to think in a rather static and conservative fashion which leads to crises and economic losses.

Chaston (1983) presents a good example of the development and crisis of the South American hake industry (aggravated since then) due to lack of proper marketing information and perspective. Another very interesting example is the fall of the Portuguese fish canning industry, once one of the most important in the world, due to a lack of both technical development and adequate marketing development.

Recent market studies (for instance Social Trends in UK, 1989, and Salmon, 1990) indicate that a number of changes regarding demand can be expected in the main food and fish markets in the coming years. These expected changes can be summarized as follows:

(i) The average consumer, particularly in developed countries, will be older (shifting from 38 to 48 years old in USA around the year 2000). The consumer will thus be more conscious and concerned about safety, quality and nutritional aspects. This tendency to healthier fishery products will also follow in developing countries, probably first in some Latin American and Asiatic countries (including China).

(ii) People will tend to eat out more often. This is due, e.g., to the increase in leisure activities and the increase in the number of working women as well as to the fact that most people in large cities eat lunch outside the home on working days. This implies that institutional and catering markets will increase and products will have to be adapted to these markets (e.g., size and weight, type of preparation).

This tendency is noted in large cities in developing countries (Mexico City, Shanghai, Sao Paulo and Lagos) where millions of people no longer return home for lunch.

(iii) The number of women working away from home will increase. In Europe, more than 50% women of active age work. This means that they have less time to cook and to purchase food, and need more prepared and semi-prepared frozen dishes (value-added products). The number of deep-freezers and microwave ovens at home is increasing both in developed and developing countries, and the frozen fish market will probably develop even further.

(iv) People in developed countries now spend relatively less of their income on food than previously, but they demand better quality food and service than before. In developing countries in general, food prices are rising and people expect better quality and service than before. This implies that rational use of resources and wise management are becoming essential in the food industry in general and in fishery industry in particular.

Levelling or reducing available fishery resources will not necessarily increase fish prices because some consumers, and particularly those from the institutional and catering markets, can easily shift to alternative products. Considering all the tendencies, it seems that the fish market will become more segmented and diversified in the future. The fishery industry will have to adapt to this tendency and respond to demand.

Large fishery industries producing commodities or utilizing a single or very few species, or producing a single or very few products with low value added, will become increasingly exposed to unforeseen market changes as happened to the Latin American hake industry. An increased proportion of fish landings will shift in the near future from the commodities area to value-added products. The tendency towards value-added (sometimes called convenience) products will be compounded by the growing urbanization in both developed and developing countries. All the current changes in the market place, challenge existing situations. At the same time, they create business opportunities for those who know the market and are in a position to use the right technology and management.

Development of fresh fish, and to some extent frozen fish markets and products, depends on supply, and in particular on the relative contribution of reared and wild fish.

Aquaculture is a dynamic sector. It has not yet reached its full potential, mostly due to the comparatively high costs of fish culture. In the last decade, improvements have been noted, especially in the culture of highly valued commercial species such as shrimp (Far East and Latin America) and fish such as salmon, seabream and turbot. The crisis of the salmon industry (1991), when prices of fresh farmed salmon dropped in some countries to the level of sardine and anchovy prices, was a clear signal of the marketing and economic constraints that aquaculture products still face in most of the world. Salmon it is not the only case, and reared seabream could hardly reach today (1995) half of the price it could obtain some 4-5 years ago, before the expansion of the aquaculture of this species. Also, the increase in aquaculture production of shrimp has shown that after a certain level of production, prices tend to fall. At the moment, aquaculture is still far from constituting an economic source of protein for people, despite the fact that countries like China have achieved impressive results.

Aquaculture will continue to develop, and will draw on other areas of knowledge, in addition to biology, in order to produce comparatively low priced products. There are still problems which might hinder its development and which must be resolved; these include fish food, intrinsic quality and organization of production, in order to achieve greater output levels. Some countries, with appropriate coast, weather and access to relatively cheap feed and energy will have advantages, e.g., the situation of Chile regarding reared salmon.

There are many factors that can affect the evolution of fisheries and aquaculture. An increase in the cost of petrol, with the resulting increase in the cost of fuel, could make the costs of aquaculture more competitive with respect to captured fish, although an increase in fuel cost will also affect the feed costs. The cost of fuel could, in the future, hinder long-range fishing and certain fisheries with a high fuel consumption. A massive, continuous, and intelligent publicity campaign could increase the market for the reared species (e.g., salmon) to overcome current market limitations.

It seems that despite the potential development of aquaculture, there will always exist a market for wild fish, to satisfy market requirements for species diversity, local and traditional foods, gourmet dishes, etc.

Cured and canned products will continue to play an important market role, especially in developing countries where refrigeration facilities, necessary for the distribution of fresh and frozen fish, do not exist. The situation will undoubtedly change where there is a tangible increase in the standard of living. International trade will continue to be very active, as demand will still not be satisfied in various regions of the world, especially in Asia, and probably in Western and Eastern Europe. The lack of conventional fish species will encourage the appearance of new products with more value added and probably the quantity of fish destined for reduction into fishmeal will decline. As already discussed, in view of the large volume of discards and by-catch losses, effort will be made to reduce them (e.g., through selective fish gear), and to utilize those that cannot be avoided.

Prediction is not a safe domain, and any prediction based on extrapolation of the current situation, or in analogies (e.g., development of aquaculture following the pattern of agriculture and husbandry) may not necessarily prove correct. The authors basically agree with the late Sir Karl Popper (1989, 1994) that there is no possibility to attain historical prediction identifying "rhythms", "trends", "patterns" or "historical laws", and that the future is basically open. Man can learn from the past if he is prepared to learn from his own mistakes, and in particular to improve a given situation if he can identify which type of activity is the result of a rational and conscious design, and which is the undesigned result of human actions (Popper, 1989).

The FAO 1995 publication, "The state of world fisheries and aquaculture", analyses the current situation of world fisheries and aquaculture, and draws a possible scenario to cover future world fish demand up to the year 2010.

2. PRODUCTION ENGINEERING

Production engineering is a vital element when conducting an economic evaluation of a process. It is applied in the project phase of an industry and is an analytical tool when production has started and deviations from the initial project appear or when modifications to the installed processes are required. When the final design phase of a process in a new project is completed, or when all technical data concerning a process in an existing plant have been collected, it is then possible to estimate the costs, as detailed specifications of equipment and complete information on the needs of the plant will be available.

First, those aspects relating to plant capacity for each of the products to be made must be analysed. For a project, examination of factors such as engineering, investments and locations, will assist in reducing the number of alternatives for selection.

2.1 Plant Capacity and Location

The size and characteristics of the target market provide the first indication to define production level and hence investment. This manual does not analyse markets in general and fish markets in particular. It does not underestimate the market component; and the importance of having appropriate market information to start or expand any industrial endeavour is recognized.

2.1.1 Information required from market studies

Market information is necessary to define production level, type of products, required technology, type of packaging, etc. In practice any industrial development starts with a number of questions: How many tons of a product can be sold? At what price? To whom? What is the current supply? The answers to these questions can be found by conducting a market survey which will establish the size of the market by estimating the quantity of a particular product that will be in demand, and its price (Samuelson, 1983). A more complete analysis of market trends can be done by studying variations in demand in relation to income, prices, demographic factors, changes in the geographic distribution of the market, and the influence of the market size on costs. As examples of this type of approach, two cases (Hotta, 1979; and Raizin and Regier, 1986) are discussed in Appendix A.

In the fishery industry, an initial analysis of the size of the market is, usually made according to the first, simpler method, as it is often difficult to access data at national or international level to produce a more exhaustive study. It must be underlined that the more information obtained on the prospective market, the better. The concept that supply adapts to demand is universally accepted. What is less apparent is that an exact understanding of the supply-demand relationship is the first step in understanding the operation of the whole economic system. A high demand or supply of a product can be created by factors other than those of the market. Governments, for political or social reasons, can decide that certain prices are too high or low and take action to establish maximum or minimum prices or impose taxes. Without analysing the advantages or disadvantages of these restrictions, the supply-demand relationship will reveal why they create scarcity or abundance.

Three markets are involved in a distribution system: markets for inputs, for fresh fish, including intermediate products (such as frozen fish), and for the final product. In the first market, variable inputs (ice, bait, labour) and fixed inputs (engines, fishing gear) are bought by fishermen, who convert them into fishing effort, which results in a quantity of landed fish. The fisherman's demand for inputs such as ice and bait, is derived from the anticipated sale of fish. In the second market, the processors buy, process and transport the fresh fish, and incur costs in the use of ice, transport, buildings and freezers. Demand for fresh fish by the processors in small-scale fisheries is derived from their anticipated income from a third market; that is, sale of their processed product to the consumers.

The dynamism of fish markets makes them difficult to define. This dynamism is due mainly to the seasonality of the catch within a year, and the changes in volume and composition of catch from one year to another. In the medium and long terms, the market for fish is also influenced by changes in eating habits, the introduction of new species, economic reasons such as the increasing cost of labour, or technological factors such as the lack of adequate packaging or the difficulty in running an efficient distribution system.

The quantity of fish distributed by the fishing sector to consumers over a period of time depends on many factors. Basically it depends on the type of resource and method of extraction, quantity of fish caught, quantity of fish demanded by the consumer, existence of flaws in the three markets, in infrastructure (landing sites, roads, transport systems) and post-harvest losses (Stevenson, *et al.*, 1982).

Small-scale fisheries use a variety of marketing systems which range from those which buy the fish as soon it is landed and sold, to sophisticated systems that involve a number of middle-men and some form of processing and the transport of fish to distant markets. Fish is bought and sold at each stage of this process, resulting in a higher price when it eventually reaches the consumer. Throughout the process, each participant takes certain financial risks with the aim of obtaining income.

Consumption of fish, as well as frequency of consumption and variety of species consumed, is increasing in Europe and the USA, as consumers become more health-conscious. Also, the marketing of fishery products has expanded much faster than that of agricultural products. Average market prices increased as a result of the increased availability of greater value added products. Increased fishery exports from developing countries has led to fishery products being one of their greater sources of foreign exchange (Zugarramurdi, *et al.*, 1988). High value added products are marketed through a complex market structure in developed countries, where a wide range of similar food products exist, whose marketing is completely different from that of traditional fishery products (Lambert, 1990). It is a dynamic market, and special strategies must be used to gain access to it.

The markets for fish generally have two components, one more or less steady which changes gradually over the years, and a variable one. In domestic markets it is relatively easy to identify both. On the international market, however, especially for producers in developing countries, it is more difficult to identify and predict the variable component. FAO, through the information services of GLOBEFISH (Headquarters in Rome), INFOFISH (Asia and the Pacific), INFOPECHE (Africa), INFOPESCA (Latin America and the Caribbean) and INFOSAMAK (Arab countries), has contributed over the years to satisfying these market information needs. These services produce marketing studies and publish newsletters on a regular basis.

2.1.2 Plant location

The cost of processing, selling and distributing a fishery product is significantly affected by the location of the plant. If the market is sufficiently large to allow several alternatives, many could be eliminated by considering the technology to be used and the location of the plant. The abundance and the regularity of supply of raw materials are the most important considerations in the selection of plant location. If different possibilities exist, a location analysis must be made for the plant, in order to select those locations that would be more economically favourable. The relative importance of the costs of inputs and their transport to the processing plant, as well as costs of production and the cost of transporting the final product to the consumers, are the three dominant geographic and economic forces. These determine whether processing should be located near the raw material supply, near the market, or in intermediary locations (Mensinkai, 1967).

The setting-up of an industry can often stimulate the production of certain goods or the settlement of a population centre. Decisions are taken to establish industries in an area precisely for this purpose. The issue of where to install the plant is clearly linked to specific policies for economic development and decentralization programmes. During the last few years in Argentina, for example, fishing activity has been concentrated in the south on the coastal zone of Patagonia, since the Argentine Government granted tax reductions to industries located in this region.

Availability of electricity must also be considered and, in some cases, if the cost is justified, internal generation must be envisaged. If electricity is not available, but raw material exists in large quantities, processing methods such as artisanal salting and drying should be examined, for the transformation of the resources into low priced, high protein foods.

Water is an indispensable input in all production activities, and its availability can influence plant location. This influence is minimal if there is water in the required quantity and quality in the vicinity of possible sites. If it is available at some locations, but not at others, this can be a very important factor in determining location.

2.2 Required Technical Information

The steps to follow in order to collect the required technical information are:

(a) Description of the production process

Description of the process through simple diagrams or flow-sheets helps in the visualization of the sequence of operations and the presentation of data. A description of the process also enables comparisons with existing techniques for manufacturing the same product(s). For a new project different technological alternatives must be evaluated and a selection made. More than one production line could be present. In the utilization of small pelagics, there could be fresh, frozen, cured and canned products. Product diversification allows for better raw material utilization and expansion of markets. Relatively simple types of processing are used for small-scale fisheries (drying, salting, smoking, freezing) (Stevenson *et al.*, 1982).

(b) Equipment selection

An assessment must be made of all the equipment and its technical features (capacity, construction material, yield, consumption, start-up operation date, estimated useful life, etc.) in order to determine limitations or bottlenecks which might hinder efficient utilization of an existing plant. For a project, this stage consists of calculating the size and type of the different equipment and installations, and specifying construction materials. The latter must be done very carefully, as the type of construction material greatly influences the mechanical design and cost of equipment. Similarly, in selecting equipment, attention must be paid to the type of process, scale of operation and level of mechanization in the plant. These factors are all closely related.

Usually, a certain level of mechanization can be applied to a minimum volume of production. A clear example is the incorporation of automatic fish grading for fish plants, which only become profitable after a certain volume of production is attained. This volume of production depends on the size distribution of the species and the cost structure of the plant, among other factors (Booman *et al.*, 1988).

There is a tendency in industrialized countries to replace the labour force by machines (automation), implying the presence of factors such as mass production, optimum organization, discipline and efficiency of the work force and good distribution systems. Using economic engineering techniques, it has been found that, in some cases, the optimum technology selected in developing countries is not necessarily the same technology used in developed countries (Cerbini and Zugarramurdi, 1981b).

Technical considerations must include relative estimates of size, features of the buildings needed for production and field distribution systems. Similarly, distribution of equipment within the industrial buildings must be considered, bearing in mind the data on yield, possibility of increasing production and material flows. This information is fundamental in estimating the fixed investment.

(c) Input assessment

Once the size of the plant is known and production method selected, the quantity and quality of each of the inputs necessary for the manufacture of each product can be determined or estimated. Determination of input requirements is the basic premise for estimating operating costs.

The main direct inputs are: raw materials, labour force, utilities and packaging. In the current situation of fishery resources, fish quantities may be fixed beforehand (e.g., catch quotas). However, even though the total fish supply may be limited, access of the single firm to the fresh or frozen fish market is free. In such circumstances, if demand increases, fresh fish prices will rise and fish processing companies may find it more interesting to import fish from abroad rather than purchasing it locally. This is the case in many developed countries today. Other raw materials may imply alternative input assessments.

When all the stages have been completed, a great amount of technical data on the process should be available. Through a careful study of the flow-sheets and the equipment, it will be possible to identify which stages of the process could be problematic, whether the problems would be recurrent or sporadic and, on examining each operation, it would be possible to foresee the problems which could materialize in the design and operation.

It must be noted that this analysis is necessary not only for the investment process, but also for an analysis of existing circumstances, since conditions or their occurrence can change with time. In developing countries, it is relatively common to find that industries have been installed based on approximate analyses, or on data from similar plants, or in political and economic situations that are far from constituting optimum or even adequate conditions for sustained development. As product quality and safety are becoming essential conditions to remain on the market and make progress, these aspects are of paramount importance during input assessment and equipment selection.

2.3 Production Technologies for Fishery Products

An in-depth study of this topic is not relevant to the objective of this manual, given the premise that any economic evaluation comes after the technical evaluation of the process. However, knowledge of the technical principles on which economic analyses are based is very important, given that an economy continues to grow as new technologies develop.

Industrialization, or the processing system, includes all the activities which involve the preservation and/or transformation of the fish and the preservation of its properties as food or for industrial raw material. Thus, through an adequately designed processing system, fish and energy can be transformed into proteins, for use as food.

There is no processing method for fish and shellfish that can improve initial quality. Fish should therefore receive the same attention and care from the moment it is caught as if it were to be consumed fresh. The different procedures to which fish is subjected for its preservation over long periods, cannot correct or conceal defects such as rancidity and spoilage.

The number of fish-based products currently in use is enormous, and new products are constantly appearing on the world market. They can be grouped, in general, as follows:

- Fresh
- Frozen
- Canned
- Cured
- Fishmeal and fish oil
- Others

The specific techniques used in these types of processing relate to food technology, and specifically, fishery products technology. It should be noted that fish was originally processed manually; later, machines came into use and now, plants are rarely without some level of mechanization. For this reason, flow-sheets are presented in the examples for both manual and mechanical types of processing. These flow-sheets show the production line in the industrial plant.

The schematic representation is limited to what takes place at a specific location and does not show how the process is performed. Therefore, when the same geometric figure is found in the diagrams (rectangle) of different processes, it does not imply that the equipment used is the same. The arrows show the sequence of operations.

Example 2.1 Flow-sheet for a Frozen Fish Plant

Draw a flow-sheet for a frozen fish plant with a daily capacity of 2 t of skinned hake fillets. The plant must produce frozen fish blocks or frozen interleaved fillets.

(a) Description of the process
(b) Equipment selection and specification

Answer: (a) Figure 2.1 shows a general flow-sheet for a frozen fish plant.

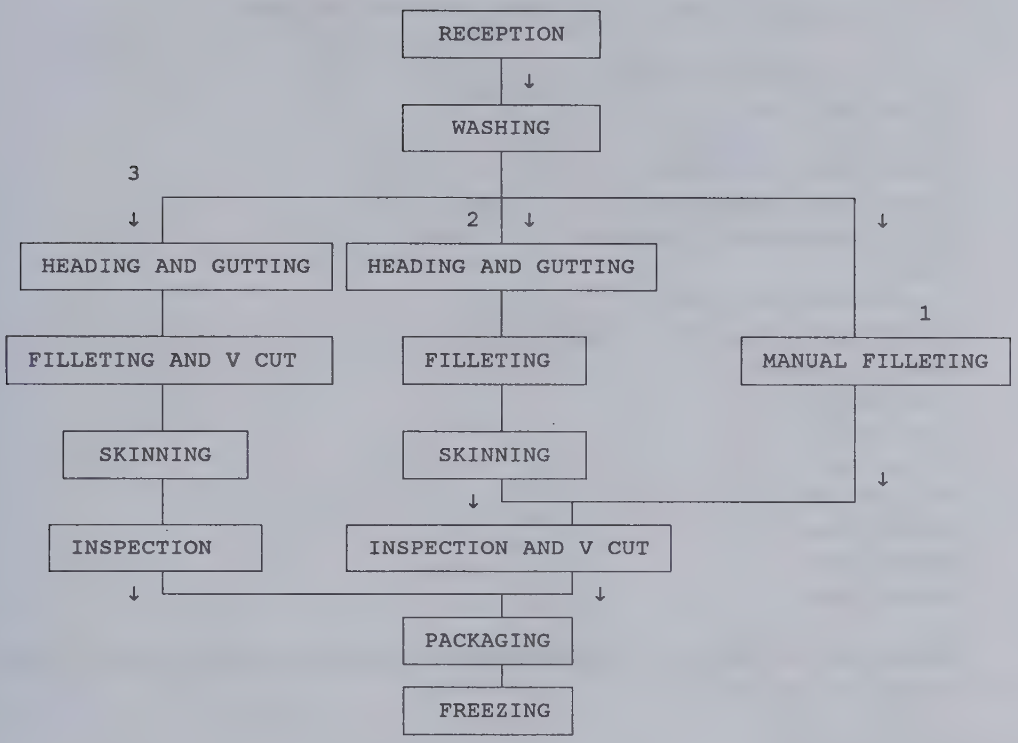

RECEPTION
WASHING
3
2
1
HEADING AND GUTTING
HEADING AND GUTTING
FILLETING AND V CUT
FILLETING
MANUAL FILLETING
SKINNING
SKINNING
INSPECTION
INSPECTION AND V CUT
PACKAGING
FREEZING

Figure 2.1 Flow-sheet for a Frozen Fish Plant

Hake fillets can be prepared manually or mechanically. In the first instance, the same worker heads and guts the fish, separating and skinning both fillets (Line 1). In the mechanical process the following equipment is needed: heading and gutting, filleting and skinning machines.

The machine-made fillet normally has to undergo two manual operations before it is completed. The first, which can be termed enhancing, is a quick procedure and consists of trimming off the black parts (rests of the skin and epithelium) still adhering to the fillet. The result of this operation is a boned fillet. Another operation can be performed along with inspection, which requires more attention from the worker. This entails a complete boning (V-cut) in order to attain a boneless fillet (Lines 2 and 3). As shown in the flow-sheet, the different lines have operations in common.

It should be mentioned that there are machines on the market that perform V-cut automatically, as a continuation of the mechanical line described above, or as part of the filleting process. After a technical and economic evaluation of the different alternatives for manual plants or plants with different levels of mechanization (e.g., 25%, 50%, 75% and 100%), the type of plant can be selected.

A study of frozen fish blocks plants in Argentina has shown that manual processing is better suited for plants with a daily capacity of less than 20 t raw material, and mechanized processing for plants above this capacity (Zugarramurdi and Parin, 1988).

(b) Equipment Selection and Specification

The following equipment is required for the frozen fish plant:

Whole fish weighing machine
Whole fish washer
Sorting table, 2 positions
Filleting table, 15 positions
Inspection and trimming table, 5 positions
Fillet packaging table, 3 positions
Scale
Fish block weighing table
Fish block packaging table, 3 positions
Strapping machine
Conveyor belts
Tray washer
Box washer
Tray remover
Freezing trays
Plastic boxes
Fork-lift truck

The number of positions to be filled for each operation is determined from a labour evaluation (see Example 2.13).

Refrigeration equipment:

Blast freezer:	5 t/24 h (*)
Plate freezer:	500 kg/load
Chill room 0°C:	20 t raw material
Cold storage - 30°C:	60 t finished product (FP)
Ice-making equipment, capacity:	3-4 t of ice/24 h
Ice storage, capacity:	2-3 production days

(*) Note: in practice, it is usual to include a blast freezer, in order to diversify the type of products that could be frozen, for example, headed and gutted (H&G) fish

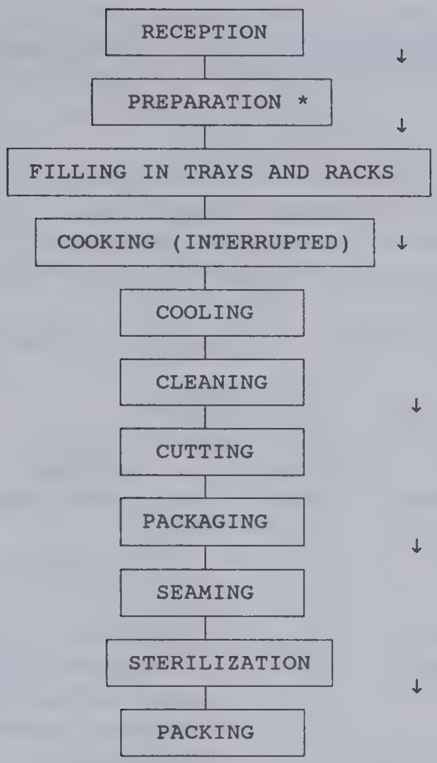
Ice-making equipment is not indispensable if ice can be bought at a reasonable price, and if continuous supply is guaranteed. This decision depends on an economic analysis of the investment necessary for an internal supply and the cost for purchasing ice.

Example 2.2 Flow-sheet for a Small-scale Tuna Canning Plant

Draw a flow-sheet for a fish canning plant with a daily capacity of 2 670 cans of tuna. Tuna fish canned in oil will be produced, using 180 g cans, with 16% covering liquid. Data for this example are taken from a small tuna canning plant in Cape Verde (FAO, 1986b).

(a) Description of the process
(b) Equipment selection and specification

Answer: (a) Figure 2.2 shows a flow-sheet for a small scale Tuna Canning Plant.



* If using frozen raw material, preparation includes thawing, heading and cutting off the tail

Figure 2.2 Flow-sheet for a Fish Canning Plant

The number of stages, or their order within the canning process, can vary according to whether large or small species are being used, whether continuous or batch processes have been chosen, whether manual or mechanical labour is being utilized, etc., but at any rate, a standard packaging process can be identified.

The fish is received and unloaded in the plant by electric winches, washed, put in brine, and transported to the heading, gutting and cutting machines. The need for cutting depends on the size of the fish.

Later, the fish is washed again and salted in brine, and finally taken to the processing area. In some industrial plants, salting is achieved by adding salt directly to the can before seaming. In the processing area, there are two possible methods by which the fish can be cooked:

Method I Canned raw and later cooked in the can (still open)
Method II Cooked, cooled, cleaned and canned

Once this stage is finished, oil is added (and salt as necessary) and the cans are sealed by automatic seaming machines. Finally, the sealed cans are sterilized in special retorts, labelled and stored in boxes until distribution.

Technological variables such as salting conditions, duration and temperature of precooking, time and temperature of sterilization, etc., must be chosen according to the species to be processed and the final product, in order to determine the most appropriate process (Parin and Zugarramurdi, 1987). In processing tuna, modifications are made to this general plan.

In the current example, Method II is used and the tuna is cooked in brine. Later the tuna is cleaned, removing the skin, bones, and red or dark muscle parts, leaving chunks and flakes of tuna. The rest of the operations are the same. When raw material is fresh, preparation includes heading and gutting, and cutting off the tail.

(b) Equipment Selection and Specifications of the Tuna Canning Plant

Reception:	1 crane
Weighing:	one 0.5 t scale
Washing:	one 2 000 l tank
Heading and gutting:	1 large table and saw
Washing:	1 tank
Cutting:	1 large table and saw
Washing:	1 tank
Placing on trays:	1 large table
Cooking capacity:	20 trays with 40 kg capacity
Transport:	1 crane and two tray carriers
Cooking:	1 insulated container
Cleaning of cooked fish:	1 large table for two workers
Packaging:	1 large table
Filling with oil and seal:	1 seaming machine: 10 cans/min
Sterilization: 1 retort:	700 cans/load
Labelling:	1 large table
Boiler:	250 kg steam/h

2.4 Input Requirements

2.4.1 Raw material

Estimates of this input can be made by working out the quantities of raw material (fish, oil, ingredients, etc.) needed to make one unit of the product. It is important to know if any by-products will be generated by this process.

With the current situation of world fisheries, yield analysis is of paramount importance to fish processing companies. In high valued products, e.g., lobster and shrimp, relatively modest increases in yield lead to substantive increases in profits. In the same way, there is the tendency to improve fish handling and processing to increase yields in commodity products. For instance, the yield in cod processing in Iceland increased by 20-26% in the period 1965-1991 (Valdimarsson, 1992). A comprehensive review of yield and nutritional value of the commercially more important fish species of the world has been published by FAO (Torry Research Station, 1989).

Table 2.1 shows the yield from fish and shellfish which are used as raw materials in the production of different fishery products. Table 2.2 shows the fish net content in different products.

Table 2.1
Yield of Different Species of Fish and Shellfish (1)

Type of Product	Yield (%)	Country	References
Canned			
Sardines (*Engraulis anchoita*)	40 - 45	Argentina	(Cerbini & Zugarramurdi, 1981a)
Mackerel (*Scomber japonicus marplatensis*)	30 - 35	"	(Parin & Zugarramurdi, 1987)
Atlantic bonito (*Sarda sarda*)	35 - 45	"	"
Hake (*Merluccius hubbsi*)	38 - 40	"	(Parin & Zugarramurdi, 1986a)
Tuna (*Thunnus spp.*)	50 - 55	Norway	(Myrseth, 1985)
Tuna (*Thunnus spp.*)	40 - 44	Tropical Countries	(Edwards *et al.*, 1981)
Tuna (*Thunnus albacares*)	38 - 40	Indonesia	(Bromiley *et al.*, 1973)
Tuna (*Katsuwonus pelamis*)	40	Cape Verde	(1990)
Shrimp (*Penaeus* and *Metapenaeus spp.*)	28	Tropical Countries	(Edwards *et al.*, 1981)
Shrimp (*Pandalus borealis*)	25 - 30	Norway	(Myrseth, 1985)
Frozen			
Hake (*Merluccius hubbsi*)			
Operation:			
Headed and gutted (H&G)	60 - 65	Argentina	
Manually filleted (Fillet with skin)	48 - 52	"	
Manually filleted (Skinned fillet)	40 - 42	"	
Mechanically filleted (Skinned fillet)	31 - 33	"	
Trimmed and V-cut	85	"	
Manually filleted (Fillet with skin)	47	Uruguay (2)	(Kelsen *et al.*, 1981)
Manually filleted (Skinned fillet)	45	"	"
Mechanically filleted (Skinned fillet)	46	"	"
V-cut	90 - 92	"	"
Product (by hand):			
Interleaved fillets, 4.54 kg	39	"	"
Interleaved fillets, 2.27 kg with skin	41	"	"
Fillet block	39	"	"
Fillet block	34 - 36	Argentina	
White croaker (*Micropogonias opercularis*) (H&G)	50 - 55	Uruguay (2)	(Kelsen *et al.*, 1981)
Whole white croaker	97	"	"
Striped weakfish (*Cynoscion striatus*)			
Fillet with skin	40	"	"
Product (by machine):			
Fillet blocks, fatless, 7.5 kg	37	"	"
Fillet blocks, standard, 7.5 kg	40	"	"
Kingclip (*Genypterus blacodes*) (H&G)	57 - 61	Argentina	
Kingclip (*Genypterus blacodes*) Skinned fillet	34 - 40	"	
Sea Salmon (*Pinguipes spp.*) (H&G)	55 - 58	"	
Prawn (*Pleoticus muelleri argentine*)			
Raw, headless	60	Argentina	
Raw, headless, skinned	45	"	

Type of Product	Yield (%)	Country	References
Shrimp (*Pandalus borealis*)			
Raw, whole	95	UK	(Graham, 1984)
Raw, headless	60	"	"
Squid (*Illex argentinus*) (Gutted, skinned)			
22-44 cm	72	Argentina	
49-62 cm	66	"	
Cod (*Gadus morhua*) Skinned fillet	31.7 - 39.4	Canada	(Mensinkai, 1967)
Gallineta (*Sebastes mentella*) Skinned fillet	24.0 - 31.3	"	"
Haddock (*Melanogrammus aeglefinus*)			
Fillet with skin	36.8 - 43.7	Canada	(Mensinkai, 1967)
Sole (*Hippoglossoides platessoides*)			
Skinned fillet	21.6 - 26.0	"	"
King crab (*Paralithodes camchatica*) (Manually processed)			
Operation:			
Batch cooking	95	Canada	(Amaria, 1974)
Continuous washing and cooking	87.74	"	"
Shell removal	66.25	"	"
Meat separation	100	"	"
Total yield:	58.13	"	"
Smoked			
Jack mackerel (*Trachurus murphii*)			
Filleted	70	Chile	(FAO, 1986a)
Smoked	55	"	"
Total yield:	38.5	"	"
Biological Silage			
Whole fish and offal (liquid product)	117	Uruguay	(Bertullo *et al.*, 1992)
" " " "	135	Venezuela	(Bello *et al.*, 1992)
Hydrolysed (Dry Product)			
Enzymatic, human consumption (Humidity:6%)	8	Cuba	(Rodriguez *et al.*, 1989)
Biological (from *Merluccius gayi* offal)	12	Chile	(Bertullo, 1989)
Dehydrated Fishery Products			
FPC (+5% from by-products: oil)	20	Senegal	(Vaaland & Piyarat, 1982)
Fishmeal	25	Brazil	"
Rolled dried fish (from minced fish)	20	"	"
Minced fish (from whole fish)	40	"	"
Mechanically and manually dried fish	31	"	"
Naturally dried and smoked	27	"	"
Fishmeal, sun-dried (tuna offal)	14	Indonesia	(Bromiley *et al.* 1973)
Wet Salted			
Anchovy (*Engraulis anchoita*)			
Headed and gutted	75	Argentina	(Lupin *et al.*, 1978)
Salted and cured	45 - 50	"	"
Anchovy (*Engraulis mordax*)			
Headed and gutted	88	Mexico	(Perovic, 1990)
Salted and cured	44.7	"	"
Mackerel (*Scomber japonicus marplatensis*)			
Cut (60%) and salted (80%)	48	Argentina	
Jack mackerel (*Trachurus murphyi*) and Spanish sardine (*Sardina pilchardus*)			
Salted and pressed minced fish (humidity: 48%)	25 - 30	Chile	(Toro Guerra, 1989)

Notes: (1) For more data see Torry Research Station (1989)
(2) Ideal standard yield, based on well handled raw material

Values in Tables 2.1 and 2.2 are only indicative. Yield and fish net content in actual products and actual plants may differ. For instance, in comparing the yield of hake from plants in Argentina and Uruguay, it should be noted that values listed in the table for

Argentina were taken from operational industrial plants. Figures given for Uruguay would only be attained if high quality raw material were processed by trained workers. It is possible to achieve an improved yield of products based on hake fillets; and in Uruguay, according to Kelsen *et al.* (1981), a 6-7% increase could be achieved.

Table 2.2
Fish Net Content in Different Products

Type of Product	Net Content (%)	Country	References
Battered and Breaded Products			
Meat content in product (%)			
Breaded shrimp	52	India	(Pedraja, 1987)
Pre-fried breaded clams	56	"	"
Pre-fried breaded squid	35	"	"
Cooked shrimp burgers	46	"	"
Cooked shrimp yield	72	"	"
Tuna burgers			
Thin	53	"	"
Large	46	"	"
Fish sticks	41	"	"
Skinned, boneless, cooked tuna yield	80	"	"
Shark burgers			
Thin	44.5	"	"
Fish sticks	41.6	"	"
Cooked shark yield	87	"	"
Pre-fried, battered, stuffed squid tubes	50	"	"
Breaded hake fillet	80	Argentina	
Prepared Foods			
Tuna in tomato sauce	47.6	India	(Pedraja, 1987)
Shrimp in tomato sauce	52.5	"	"
Canned			
Sardines (*Engraulis anchoita*) 170 g ea	75 - 80	Argentina	(Parin & Zugarramurdi, 1987)
Sardines (*Clupea pilchardus*) 125 g ea	72	Tropical countries	(Edwards *et al.*, 1981)
Sardines 125 g ea	76	Norway	(Myrseth, 1985)
Herrings 195 g ea	67	"	"
Mackerel, 195 or 250 g ea	67 - 72	"	"
Shrimp, 111 or 217 g ea	67 - 69	"	"
Tuna, 125 or 200 g ea	76 - 77.5	"	"
Fish cakes, 400 or 800 g ea	65	"	"
Sardines, 125 g ea	72	Tropical countries	(Edwards *et al.*, 1981)
Shrimp, 200 g ea	64	"	"

The yield of each operation and the final production yield must be known. It is also important to know how yield varies according to the quality of raw material, the training of the worker, size of the fish, change in the sequence of operations, etc. Published results indicate that the raw material yield diminishes when there is a lack of: quick icing onboard (10-15%) and sorting (7%). In the case of fish near the acceptability limit, the yield reduction could be up to 25% (e.g., anchovies for fish salting). Raw material quality has a great impact, since in addition to the decrease in yield it increases labour and in practice reduces production capacity (Montaner *et al.*, 1994a). Actual yields should be researched in each plant. Table 2.3 shows the yield values for production of interleaved hake blocks according to quality of raw material and worker training (from Kelsen *et al.*, 1981).

Table 2.3
Final Yield by Quality of Raw Material and Worker Training

Quality of raw material	Good	Good	Average	Average
Worker training	Good	Average	Good	Average
Final yield (%)	39.3	34.7	36.5	32.2

If an operation performance is defined as the variation in yield for good or average quality raw material over highest yield, it will decline by 7%, whereas if both quality and training are considered, the value increases to 18%. Table 2.4 shows that the highest yield is achieved when sorting is done before processing (from Kelsen *et al.*, 1981).

Table 2.4
Overall Yield of Frozen Unglazed Mechanically H&G Croaker (*M. opercularis*). Effect of Sorting by Size

Yield (%)	With sorting	Without sorting
Actual	48	44.3
Ideal *	50 - 55	-

* Based on quality and handling of raw material

Given the high percentage of the cost of raw material in the final production costs, all recommendations for the treatment of raw material must be considered in order to maintain the initial quality of the fish. It is essential that the FIFO principle (first in, first out) be applied, rigorously controlling the order in which raw materials are processed, in order to achieve a high final yield. Finally, Table 2.5 shows the use of other raw materials such as salt, oil, etc., in the production of fishery products.

Table 2.5
Consumption of Various Raw Materials in the Production of Fishery Products

Type of Product	Consumption	Country	Reference
Battered and breaded products			
Tuna burgers			
Bread	12-31% of product weight	India	(Pedraja, 1987)
Stuffed squid			
Battered and pre-fried			
Stuffing	30% of product weight	India	(Pedraja, 1987)
Batter	20% of product weight	"	"
Smoked yellow jack mackerel			
Salt	0.1 kg/kg of fresh fish	Chile	(FAO, 1986a)
Sugar	0.07 g/kg of fresh fish	"	"
Canned			
Oil	0.1 kg oil/kg sardine raw material	Argentina	(Parin & Zugarramurdi, 1987)
	0.25 kg oil/kg final product	"	"
Salt	0.012 kg salt/kg of whole sardine	"	"
	0.03 kg salt/kg of sardine final product	"	"

Example 2.3 Raw Material Requirements

Calculate the consumption of raw material for the frozen fish plant in Example 2.1. The raw material is whole hake.

Answer: To determine the quantity of raw material required for obtaining 2 t of finished, skinned, hake fillet, all that needs to be known is the total yield of the operation. Table 2.1 shows that the yield for manual production of skinned, boned, frozen hake varies between 34 and 36%.

$$\text{Raw Material Required (t)} = \frac{\text{Plant Capacity in Finished Product}}{\text{Yield (decimal)}}$$

$$= \frac{\text{2 t of fillets}}{\text{0.34 (t whole/t fillets)}} = 5.9\text{ t}$$

Thus, 5.9 t of whole hake will be required to produce 2 t of skinned fillets.

Knowing the yield of each operation is useful to compare actual yield with theoretical yield and assess how efficient the operation is or to discover what or where the losses are. When the yield of different stages of processing is analysed, calculations can be more complicated, as the basis for calculation varies. An example follows:

Example 2.4 Raw Material Requirements, by stage

Calculate the consumption of raw material, at each stage, filleting, trimming, and V-cut for the frozen fish plant using manual processing, described in Example 2.1. The raw material is whole hake.

Answer: Generally, the results are expressed in terms of units of finished product (in this case 1 kg of finished fillet). This value is obtained by multiplying the weight (kg) of the product at each stage by the yield of the stages which have not yet been completed.

Graphic representation of the effect of the processing of fish:

Whole hake		Filleted		Trimmed
1 000 g	→	400 g	→	340 g

The 5.9 t of whole raw material gives a yield of 34% when filleted.

5.9 t raw material x 0.4 = 2.36 t of fillets (un-trimmed)

2.36 t of fillet x 0.85 = 2 t of finished product (skinned, boned fillets)

Overall yield = 0.4 x 0.85 = 0.34 (or 34%)

Example 2.5 Raw Material and Input Requirements

Calculate the use of raw material for the fish canning plant in Example 2.2. The raw material is tuna.

Answer:

Fish: To calculate the quantity of fish required for daily production of 2 670 cans, the following formula will be used:

$$\frac{\text{Daily Production (cans/day) x Net weight (kg/can) x (1 - filling, expressed as a decimal)}}{\text{Total yield (decimal)}}$$

$$= \frac{2\ 670 \text{ cans/day} \times 0.180 \text{ kg/can} \times (1 - 0.16)}{0.4} \quad \begin{aligned} &= 1\ 009 \text{ kg raw material/day} \\ &\approx 1\ 000 \text{ kg raw material/day} \end{aligned}$$

(filling: oil, brine or sauce added to canned fish during processing)

Oil: Daily production (cans/day) x Net weight(kg/can) x Filling expressed as a decimal =
2 670 cans/day x 0.180 kg/can x 0.16 = 77 kg oil/day ≈ 80 kg oil/day

This calculation is the exact quantity that must be added to the can. During actual plant operations, however, a greater quantity is consumed, usually 1-2%, due to losses.

Salt: Daily production (cans/day) x Fish content (kg/can) x (1- filling expressed as a decimal) x Salt expressed as a decimal =
2 670 cans/day x 0.180 kg/can x (1-0.16) x 0.03 = 12 kg salt/day

Thus, 1 t of tuna, 80 kg of oil and 12 kg of salt will have to be utilized daily in order to produce 2 670 180-g cans of tuna in oil per day.

The values in Tables 2.1 to 2.5 and other tables with numerical values which appear in the text, must be taken as illustrative values, to serve as guides in a first analysis of the processes. It is clear from analysing these tables that in practice there are variations in the values published by different authors. These variations are due to diverse causes that the technologist must be able to identify in each specific case, and which generally pass unnoticed in common economic analyses. The authors opine that widespread and indiscriminate use of factors in calculating yield and inputs is one of the reasons for the failure of undertakings in this area.

The following example analyses causes for variation in use of salt in fish salting.

Example 2.6 Technical Analysis of the Use of Salt in Fish Salting

Make a technical analysis of the use of salt in fish salting

Answer: Only a certain quantity of salt can be absorbed by fish flesh. At saturation, this quantity is equal to the amount of salt that would dissolve in a quantity of water equal to what the fish might have at the moment of establishing equilibrium; that is, the salt is mainly forming a brine, of the same concentration as can be found outside the fish, inside the fish flesh.

The flesh cannot absorb solid salt (Zugarramurdi and Lupin, 1976, 1977). From this, it is possible to calculate the minimum quantity theoretically needed to salt fish. For example, for salting anchovies and other small pelagics, Mediterranean style (headed and gutted fish, simple or butterfly fillets, wet salted, with pressure, for a product with a water activity value of 0.75), the quantity of salt required can be estimated at 20-25% of the total fish weight to be salted (variation is due to the lipid content). This minimum quantity is generally not recommended, since it is desirable for the container to have an excess of salt.

The excess salt in the bottom of the salt barrel guarantees that the fish has been saturated with salt (a control for the process). Thus, in practice, a higher percentage of salt, 30-40% of total fish weight, is recommended for this process (Lupin, Zugarramurdi and Boeri, 1978). From the point of view of inputs, this quantity can be greater due to other factors such as quality or coarseness of the salt or a different salting process.

If the salt is impure and dirty, as happens with many solar produced salts in developing countries (salt produced directly from the action of the sun on seawater), the salt must be washed before it is used for salting fish (washing with tap water is sufficient to eliminate substances such as sand, reduce the content of other salts and also reduce level of contamination by halophilic bacteria). Depending on the intensity of washing, 10-20% more salt may have to be used.

If the process is dry salting (i.e., accumulated brine is drained), more salt is added so as not to risk spoilage due to insufficient salt. It is not easy to estimate this quantity, as it depends on the coarseness of the salt and other factors such as type and shape of fish to be salted.

If the available salt is very fine (crystal size of 0.5-1.5 mm) brine drainage will take a large quantity of the salt with it. If the salt used is of a larger grain (more than 3-5 mm) a larger quantity of salt will be required to ensure that the various layers of fish in the dry stack are covered with salt. For best results (one-third fine crystals to ensure rapid brine formation on the fish and two-thirds crystals of 3-5 mm size to maintain brine saturation), an estimated 20-30% more salt will be needed for the dry-salting process.

In calculating total inputs, account must be taken of salt losses incurred in transportation and storage. These losses are obviously related to the quantity of salt used, care in handling and storage, etc. Losses can be estimated at approximately 10%.

Salt content in the final product will depend largely on the pressure. Products which are wet salted without pressure weigh more when finished, and their brine content (and therefore salt content) is greater than those wet salted with pressure. Products which are wet-salted without pressure will require additional salt.

It can be estimated, for example, that a wet-salting process using pressure, where the salt needs to be washed, will require a quantity of salt equivalent to 50-70% of the total weight of the fish already prepared for salting. If it is desirable to relate this quantity to raw material, and assuming a yield of 75%, between 37 and 52% of the weight of the raw material will be required in salt.

It could be argued that in practice, the cost of salt could have little influence on total cost, and that a detailed analysis would therefore not serve any real purpose. This could be the case, for example, with the salting of cod in North European countries. However, there are countries and types of exploitation where the cost of salt is a major and significant input.

The authors have found that salt cost can rise to US$ 1-2/kg in remote islands (in Asia and in the South Pacific) and in the interior of Africa when transport difficulties exist. For instance, an FAO project carried out in the Maldives demonstrated that the only economically viable possibility for fishermen located in islands far from the capital, to produce salted fish, was to produce their own salt.

In short, analysing inputs must be considered in reference to a particular process, in a specific area or country, and within a general cost structure.

A summary of this analysis is shown in Table 2.6.

Table 2.6
Technical Analysis of Salt Consumption

Process	% of salt needed (kg salt/kg fish to be salted)
Wet salted	
- with pressure	30 - 40
- without pressure	40 - 50
Dry salted	
- normal	50 - 60
Salt washing	10 - 20
Losses	10

The previous example illustrates the difficulties in making a technical analysis of a process as simple as salting. The analysis of an input at the industrial level is, in practice, more complex.

2.4.2 Ice consumption

The amount of ice required to chill and store chilled fish depends on several factors, and there is no immediate rule to calculate it. However, when the situation is repeated every day, when it is necessary to purchase an ice plant, to calculate a chilled fish distribution chain or to furnish ice to a fleet, an accurate calculation of the ice requirements must be made.

Common fish handling advice is usually based on the use of concepts like "plenty of ice" and "re-icing". The simple rules found in many technical publications are matters of discussion in many practical situations. Moreover the economic impact of the cost of icing fish (cost of ice plus quantity required) in developing countries is different from that in developed countries where it can be considered negligible.

The ice consumption in icing fish can be divided into three terms:

$$\boxed{\begin{array}{l}\text{Total ice}\\ \text{consumption}\end{array}} = \boxed{\begin{array}{l}\text{Ice necessary to}\\ \text{cool fish to }0^\circ\text{C}\end{array}} + \boxed{\begin{array}{l}\text{Ice melted to}\\ \text{compensate for}\\ \text{thermal losses}\end{array}} + \boxed{\begin{array}{l}\text{Ice}\\ \text{handling}\\ \text{losses}\end{array}} \qquad (2.1)$$

The division in different terms is useful to evaluate the extent and weight of the losses.

The ice necessary to cool fish to 0°C can be calculated theoretically, i.e.

$$\text{Ice necessary to cool fish to }0^\circ\text{C} = \frac{c_{pf} \text{ x } T_f}{\lambda} \text{ x } M_f \qquad (2.2)$$

where:

c_{pf} = specific heat of fish (kcal/kg°C), the c_{pf} varies with the composition, it will be around 0.80 kcal/kg.°C for lean fish, 0.78 kcal/kg.°C for medium fatty fish and 0.75 kcal/kg.°C for fatty fish
T_f = fish temperature (°C), usually taken as the sea water temperature
λ = latent heat of fusion of ice (kcal/kg), usually taken as 80 kcal/kg
M_f = mass of fish

If all the factors are put together in Equation (2.2) the following equation is obtained for lean fish:

$$\text{Ice necessary to cool lean fish to }0^\circ\text{C} = \frac{T_f}{100} \text{ x } M_f \qquad (2.3)$$

or

$$\text{Ice necessary to cool 1 kg of lean fish to }0^\circ\text{C} = \frac{T_f}{100} \qquad (2.4)$$

Equation (2.4) can be taken as a quick approximate way to calculate the amount of ice to cool down fish to 0°C (in all the other cases the required amount of ice will be lower than such required for lean fish). For example, if fish caught is at 25°C, the result will be 0.25 kg ice/kg fish. Why in practice is much more ice necessary?

The general answer is to compensate for losses; the most important losses are thermal. Ice is utilized to cool down fish to 0°C, and in doing so, ice melts. Ice melting rates, due to thermal losses, depend mainly on external temperature and the type of container where the iced fish is stored (in particular the insulation characteristics of the container's walls, and its geometry). It can also depend on how and where the fish boxes or containers are stacked. In general the equation that relates the ice melted to compensate for thermal losses will be:

$$M_i(t) = M_i(0) - k \text{ x } \bar{T}_e \text{ x } t \qquad (2.5)$$

or

Ice melted to compensate for thermal losses = $M_i(0) - M_i(t) = k \times \bar{T}_e \times t$ (2.6)

where:

$M_i(t)$ = mass of ice in the box/container at time t (kg)
$M_i(0)$ = initial mass of ice in the box/container at time t=0 (kg)
$\bar{T}_e$ = average external temperature (°C)
t = time elapsed since icing (hours)
k = specific ice melting rate of the box/container $\frac{\text{[kg of ice]}}{\text{[hour x °C]}}$

The k value can be very easily determined experimentally in boxes (Boeri *et al.*, 1985) and insulated containers (Lupin, 1985a). In principle it could be determined theoretically from the box/container thermal characteristics; however, in practice, wide variations can be found due to the lid type, drainage and to a lesser extent due to the type of ice and the actual volume occupied by fish and ice in the box/container.

The experimental determination of k is advised particularly when large volumes of ice are utilized. In actual conditions the external temperature (T_e) fluctuates. However, acceptable calculations are obtained assuming an average temperature ($\bar{T}_e$), from the beginning until the end of the specific storage trial. In this case, the following relationship can be defined:

$$k' = k \times \bar{T}_e$$

For example, the values of k and k' for two types of fish containers are as follows:

(i) Standard plastic box (polyethylene, 40 kg, Boeri *et al.*, 1985)
$k = 0.22$ (kg of ice/day x °C)
$k' = 0.22 \times \bar{T}_e$ (Kg of ice/ day), (regression coefficient, r = 0.98) (2.7)
(ii) Insulated container (Metabox 70 DK, Lupin, 1985a)
$k = 0.108$ (kg of ice/day x °C)
$k' = -0.04 + 0.108\,\bar{T}_e$ (kg of ice/ day), (regression coefficient, r = 0.98) (2.8)

Ice stored at ambient temperature has a certain amount of water on its surface: this means that when ice is weighed a certain part of the weight is already water. The larger the ice surface per unit of volume, the higher the amount of water in equilibrium. The amount of water in equilibrium in sub-cooled ice is nil (the ice sticks to the fingers), and in ice bars is negligible. However, in all the other types of ice stored above 0°C, it has a value. In Table 2.7 the measured amount of water in equilibrium for different types of ice is shown:

Table 2.7
Average Percentage of Water in Equilibrium in Different Types of Ice, Stored at 27°C
(Boeri *et al.*, 1985)

Ice type	Equilibrium water (% wt/wt)
Flake ice	12 - 16
Crushed block ice	10 - 14
Ice chips	16 - 20

Additional losses are due to bad handling and melted water in equilibrium over the ice surface. Losses due to bad handling (e.g., ice fallen on the floor or thrown away when ice in boxes or containers is levelled) are very difficult to assess since they depend on many factors (including worker's skill), but they are probably not lower than 3-5% of the amount of ice utilized. Apart from the effect on the economic performance this type of loss should be reduced as much as possible for reasons of hygiene and working safety.

All calculations on ice consumptions should be made on a weight basis, since different types of ice have different volumes for the same weight, and the cooling capacity (latent heat of fusion of ice) is expressed in kcal/kg. Water from melted ice, even at 0°C, has a negligible cooling effect on fish (it is useful for other purposes, e.g., to improve heat transfer, to keep the fish moist).

A consolidated picture of the different ice requirements is given in Table 2.8.

Table 2.8
Some Values of Ice Required for Icing Fish

Consumption/loss factor	Ice necessary (kg), or (kg/day)						Ref.
	T_f or $\bar{T}_e$ (°C)						
	1	2	5	10	20	30	
- To cool down 1 kg of fish to 0°C	0.01	0.03	0.05	0.10	0.20	0.30	Eq. (2.4)
- To compensate for thermal losses (in kg/day for a given box/container)							
Examples i) Standard plastic box (40 kg) (Boeri *et al.*, 1985) (1)	0.22	0.44	1.1	-	-	-	Eq. (2.7)
ii) Insulated container (Metabox 70) (Lupin, 1985a)	0.068	0.176	0.5	1.04	2.12	3.2	Eq. (2.8)
	Ice necessary as % of the initial mass						
- To compensate for bad ice handling	3 - 5 (2)						
- To compensate for water in equilibrium	12 - 20 (3)						Table 2.7

Notes: (1) Experiments were carried out only between 0° and 5°C, values correspond to a box stacked in the middle of a stack
(2) Minimum estimated values
(3) Depends on type of ice and storage temperature

It is interesting to analyse results for $\bar{T}_e$ from 1°C to 5°C in Table 2.8 to assess ice consumption when a chill storage room (or chill storage hold) is utilized, and values of $\bar{T}_e$ from 10°C to 30°C to analyse when iced fish is stored/transported at ambient temperature in standard boxes or insulated containers, particularly in tropical conditions.

A wide variety of situations exists and the recipes (e.g., "use 1:1 ratio", "use 1:2 ratio") are, therefore, meaningless. This type of recipe is at the root of many past failures when attempting to introduce ice in artisanal fisheries in tropical developing countries, because they may lead to technical and economic mistakes.

A systematic approach for the ice consumption in insulated containers is available in the literature (Lupin, 1985b); however, approximate estimations can be made from the data in Table 2.8 (for other types of boxes/containers, the experimental determination of k is advised).

2.4.2.1 Fish to ice ratio

In practice, a ratio fish to ice (or ice to fish) is defined as follows:

$M_f/M_i^o = n$ (2.9), or: $M_f = n \times M_i^o$ (2.10)

Also, as a container has a finite volume, the following relationship holds at $t = 0$, assuming the container is completely full:

$$V_c = M_f \times V_{sf} + M_i^o \times V_{si} \qquad (2.11)$$

where:

V_c = internal (utilizable) volume of the container (cm^3)
V_{sf} = specific volume of fish stowed (cm^3/kg)
V_{si} = specific volume of ice stowed (cm^3/kg)

In the experiments mentioned by Lupin (1985a), the values of V_{sf} and V_{si} are:

V_{sf} = 1274 cm^3/kg (barracuda *Sphyraena* spp., Tanzania)
V_{si} = 1731 cm^3/kg (flake ice)

It should be said that V_{sf} and V_{si} can easily be determined in actual conditions by weighing a known volume of fish or ice. In order to determine how long ice will last in the container, some of the above relationships may be rearranged to obtain the time that is necessary to keep the mixture of fish and ice (t_{MAX}), which is usually fixed by the conditions of storage and transport. It is possible to define a t^*_{MAX} when no fish are in the container and all the ice is used to compensate heat losses. In this case:

$$t^*_{MAX} = \frac{V_c}{V_{si} \times k \times \bar{T}} \qquad (2.12)$$

All the above expressions can be rearranged to:

$$n = (V_{si}/V_{sf}) \times \frac{1 - \dfrac{t_{MAX}}{t^*_{MAX}}}{\dfrac{t_{MAX}}{t^*_{MAX}} + (V_{si}/V_{sf}) \times C_{pf} \times T_f/\lambda} \qquad (2.13)$$

Equation (2.13) is represented in Figure 2.3 for three different fish temperatures.

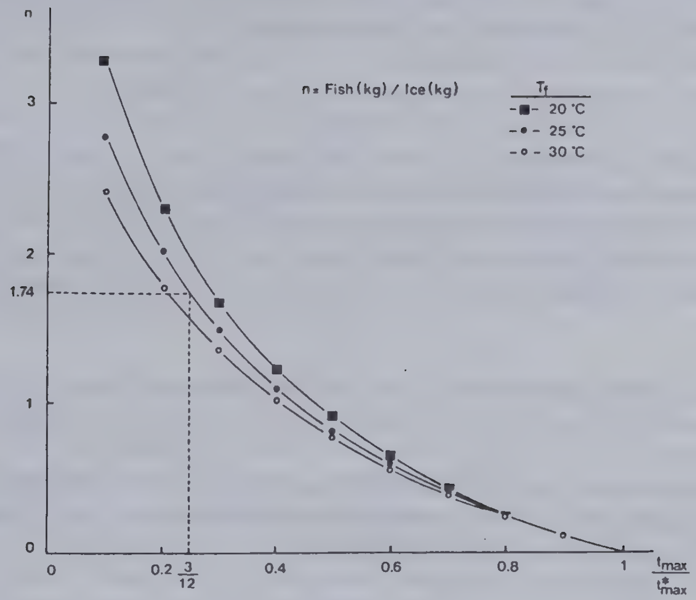


Figure 2.3 Fish to Ice Ratio to Satisfy a Given t_{MAX}/t^*_{MAX} Ratio with V_{sf} = 1 274 cm³/kg, V_{si} = 1 731 cm³/kg

On the other hand, t^*_{MAX} can be represented as a function of T_e for a given type of container, using expression (2.12). This equation is represented in Figure 2.4 for the Metabox 70 container (Lupin, 1985a). Figure 2.4 can be determined after an evaluation of the thermal effectiveness of the container (Lupin, 1985a).

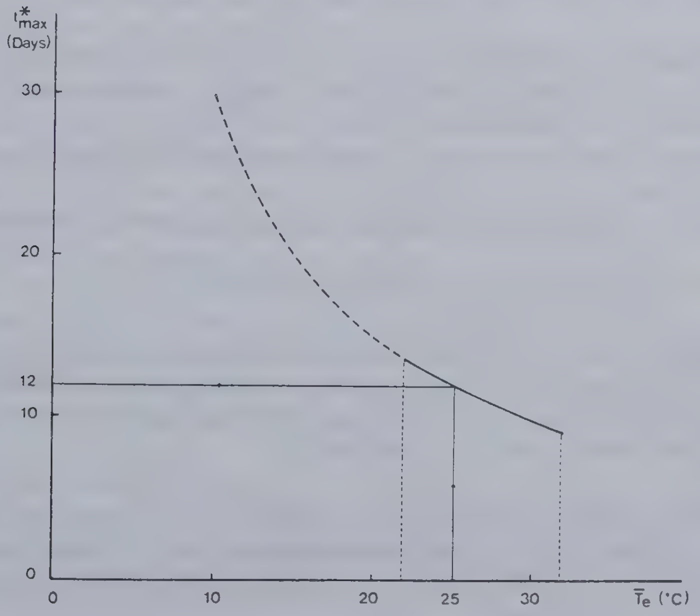


Figure 2.4 Variation of t^*_{MAX} as a Function of $\bar{T}_e$ for the Metabox 70 Container

It is important to discuss ice consumption, particularly in developing countries. As will be seen later, 1 kg of ice can, in many places, represent a significant proportion of the cost of 1 kg of fish and is sometimes even more expensive.

Example 2.7 Introducing Plastic Boxes in Artisanal Fisheries

Fish is plentiful near the islands off the coast of Ruritania; however, it takes up to six hours for iced fish to arrive from the island villages to the capital city where a growing fish market exists. Ice is available in the capital city and arrangements can be made to return the fish boxes (after washing) full of ice. Plastic boxes were recommended because they were found more hygienic than local wooden boxes (public officers are concerned about public health aspects).

Average temperature in Ruritania is around 30°C. It was suggested to utilize standard plastic boxes covered by a tarpaulin to do the job. Do you think it is feasible?

Answer: As recommended in section 2.4.2, an experimental determination of ice consumption was carried out in order to obtain reliable results at the expected working temperatures. The results are presented in Table 2.9.

Table 2.9
Ice Consumption in Plastic Boxes in the Tropics (1)

Box type	Storage	$\bar{T}_e$(°C)	k (kg ice/hour)
- with drainage (2)	Shade	28	1.13
	Sunshine	30.4	3.12
- without drainage	Shade	28	2.13
	Sunshine	30.4	5.30

Notes:

(1) Actual experiments were conducted at the FAO/DANIDA Workshop, Guinea-Bissau 1986, with plastic boxes of about 35 kg (of water) capacity each. Full flake ice capacity about 20 kg. Measurements done on individual (not stacked) boxes.

(2) Water retained in the box allows for better heat transfer and therefore increases the ice melting rate.

(3) There may be an influence of radiation in the case of boxes exposed to sunshine.

From Table 2.9, it is possible to deduce the following:

(i) Plastic boxes without the coverage of a tarpaulin (shade) cannot be utilized since exposure to sunshine increases dramatically the ice melting rate (around 160% over the ice consumption in the shade) and, in any case, ice will be melted before it arrives on the islands.

(ii) Plastic boxes without drainage showed, in this case, an increased ice consumption even in the shade and in the best of cases, only a reduced fraction of the initial amount of ice in each box (about 13 kg per box) will arrive on the islands.

About 10 kg of fish could be fitted in each box (almost the 1:1 ratio). Chilling the 10 kg of fish will take around 3 kg of ice, and the journey back to the capital will consume a little less than 7 additional kg of ice. In principle, there are still 3 kg of ice per box left to provide for loading and unloading time and unexpected delays and other losses.

However, the risks of delays should be carefully assessed and the economics of utilizing 2 kg of ice to transport 1 kg of fish should be analysed before taking a decision. Moreover, if fish is to remain overnight in the capital city (and this is a possibility) before being sold the following day, it will be necessary to re-ice the fish a couple of times and total ice consumption will rise to 4 or 5 kg/kg of fish and ice costs will become prohibitive. In most cases, unless an expensive product is involved (e.g., shrimp), this procedure will not be viable and another solution must be sought.

Example 2.8 Introducing Insulated Fish Containers in Artisanal Fisheries I

The insulated container of Table 2.8 will lose 0.8 kg of ice en route from the town to the village; each container will have a large amount of ice, enough to fill it with fish and reship it back to town. Ice will be sufficient to compensate for other losses that may occur, for instance an overnight wait for the ferryboat early in the morning. As in this case, a proportion of 1 kg of ice per 2 kg of fish will be more than enough to transport fish to town; not all the incoming insulated boxes need be full of ice. However, fishermen may require additional ice to keep fish fresh if not caught a few hours before shipping the fish to town.

This example shows that the introduction of insulated containers could be a sound technical solution. However, it introduces additional costs (ice plus insulated containers) and a type of relationship and coordination between purchaser and buyer that may not exist. In this situation, extension services have a lot of work to do.

Example 2.9 Introducing Insulated Fish Containers in Artisanal Fisheries II

Continuing with the situation described in examples 2.7 and 2.8, it could be assumed that the introduction of insulated containers analysed in 2.8 was initially a success. Local extensionists and foreign technical assistance run a scheme that gave good results, increased the quality and amount of fish shipped to town and the fishermen's income.

At a certain point, the extension service decided to stop the assistance and passed operations onto the fishermen and buyers. Everything was fine for a while until certain problems arose. The first was that the success generated the interest of fishermen in more remote islands in the archipelago and fish was arriving in the village in quantities that required much more ice than before. It was now necessary to reship ice to the most remote islands from the village. At the same time, the system required a coordination and understanding between buyer and seller not always easy to achieve. Sometimes, the ferry did not arrive and this generated fish losses because ice was insufficient to keep all the fish until the next day. Ice and fish storage capacity is now necessary at the village.

The installation of an ice plant and a cold storage room in the main fish village may now be an attractive possibility provided the village has enough electricity; if not, a generator could be installed. In any case, this possibility should be checked out from an economic point of view, to determine if it is self-sustainable.

An alternative transitory solution could be to transport ice bars from the capital city to the village. Ice bars melt slowly and take less volume per unit of ice weight (making transport and storage less bulky). Fishermen could crush the ice just before using it to chill fish. This alternative is used by artisanal fishermen in countries like Colombia, Philippines and Senegal where they have developed the system by trial and error. The ice bar solution gives fishermen a little more flexibility than the flake ice solution and does not require much investment. However, extensionists should study the feasibility of this system carefully, considering time and distance from the market, before they advise it.

There is a second transitory solution: to increase the volume of the insulated containers. As thermal losses are proportional to the area exposed to the air, the increase in volume will reduce the ice losses per 1 kg of fish (and per 1 kg of ice when transported and stored). The drawback of this solution is that insulated containers could become too heavy to move for loading and unloading; at the same time, in large containers there is the risk of fish losses by mechanical damage and lack of proper icing. Despite this limitation, large insulated containers can be found in operation, e.g., in Tanzania and Uganda.

This example could be complicated in different ways, for instance, the ferry company may impose a maximum volume on transport because passengers and other goods should also be transported (not an unlikely situation in some African countries). Development is in practice a continuum of situations, very difficult to assess beforehand. This example shows that a technical solution does not necessarily work forever even if initially successful. The raw material calculation, in this case ice, may be affected for many different reasons, to be specified in each case. Theoretical calculations (application of equations 2.1-2.6) are obvious; therefore, examples 2.8 and 2.9 mainly aim to clarify that determination of actual conditions to which such calculations apply is the first important step.

Example 2.10 Ice and the Fish Quality for a Given Market: the Zero Ice Option

For many years the fishermen in the previous example were sending un-iced fish in artisanal containers to the capital city (they knew which type of fish was suitable). Local customers were waiting for the fish and it can be calculated that the fish was consumed around 10-12 hours after being caught. It was not the best solution but in the past it worked.

However, the capital city of Ruritania grew considerably and a fish market was organized by the Government. Now the customers can no longer buy directly from the fishermen and have to go to the market. Obviously, it takes considerably longer than before for the fish to reach the customer and, as restaurant owners and fish exporters are also buying fish from the fish market, they complain about the quality of the fish from the islands.

The Government does not want to return to the previous situation and, moreover, wants to enforce rigid hygienic and sanitary regulations to protect public health and exports. The Government fish market was organized to expand the supply, to curb excessive middle-man action to benefit both fishermen and consumers, and to improve fish hygiene and quality which were at risk in the former informal market with the increase of fish consumers.

Fishermen do not understand how things changed so suddenly, and this is the situation that generated the proposition discussed in Example 2.7. Imagine you are a Government Fish Extensionist - how could you explain the situation to the fishermen?

Answer: Iced fish is almost synonymous with fresh fish. However, there is a very short period - immediately after catch - during which fresh fish may stay without ice. Fish spoils very quickly but if it is kept moist, in the shade, and away from filth and animals, it keeps its edible quality for some hours; there is no fixed rule on how long since this depends largely on the type of fish. For instance, some small pelagics can develop a large amount of histamine after only 4 or 5 hours of storage at ambient temperature (Ababouch, 1991), but other species - in particular some lean and flatfish - can last longer.

Fishermen know usually from their own experience how long this period can be and they also know that the fish should be consumed as soon as possible and cannot last till the following day in such conditions. However, when additional delays are introduced, or when fish is not consumed right away or needs further processing or when the middle-man chain expands, the picture changes dramatically, since fish in such conditions lose quality which cannot be recovered. Moreover, the fish may become unsuitable for consumption from the health point of view.

The zero ice consumption option works within very narrow time limits and temperatures and is generally the first stage of the fish consumption development pattern. It comprises the subsistence condition and early marketing stages when quick consumption or processing follows landing, very few hours after catching.

Example 2.11 Ice Consumption in a Fish Chill Room

In an industrial plant, fish iced in flake ice is stored in a chill room (average 5°C) in 40 kg plastic boxes. Normally fish stay in the chill room about 12 hours. The manager wants to know the effect of reducing the temperature of the chill room from 5° to 3°C. Apart from reduction in ice consumption what additional benefits could be expected?

Answer: Following the figures of Table 2.8, the calculations are as follows:

Table 2.10
Ice Losses in a Chill Room

Condition	Thermal losses in 12 h (kg)	Ice handling losses (kg) (4% of total)	Water in equilibrium (12% of total)	Total ice needed (kg)
Box at 3°C	7.92	0.32	0.95	9.10
Box at 5°C	13.20	0.53	1.58	15.31

Thus, reduction of the chill room temperature from 5° to 3°C will mean a reduction in ice requirements of about 40% (the economic convenience of reducing the chill room temperature should be checked independently). The reduction of the amount of ice required means in practice a net increase in the fish storage capacity. The increase in terms of weight depends on the specific volumes (cm^3/kg) of fish and ice stowed in the boxes. Assuming that the specific volume of flake ice is 1 731 cm^3/kg, and that a small type of fish of 1 300 cm^3/kg is stowed (Lupin, 1985b), a total of 10 593 cm^3 will be available per box which, in practice, will allow more than 8 kg of additional fish per box. This is not a negligible amount.

Utilizing the same specific volumes it is possible to calculate that in the 5°C storage situation, the amount of fish cannot be higher than 10 kg per box (please note that a box of

40 kg will contain 40 kg of water and the weight of ice and fish contained will be much lower). This means that a reduction in the chill room temperature from 5° to 3°C will give an increase of around 80% in the actual fish chill room capacity.

These results which are known to the well-experienced fish chill room operators are systematically ignored and the ingrained tendency to follow general and untested recipes unfortunately prevails. Whereas this aspect may be of little importance in developed countries (to be verified), they became important in developing countries where there is a need for better ice and fish chill room design and management. However, it is expected that the current trend towards the application of quality assurance concepts that also involve yield, economics and management, as well as fish quality, will subject all fresh fish handling and processing procedures to a more rational analysis.

Example 2.12 Fish to Ice Ratio Calculations

Determine the appropriate fish to ice ratio for a given set of conditions in two different developing tropical countries and compare the results obtained for a temperate developed country. (Real data were compiled by the authors during the FAO/DANIDA Regional and National Training Workshops on Fish Technology and Quality Control.)

Answer: From values in Table 2.11 and equations (2.12) and (2.13), values in Table 2.12 can be obtained.

Table 2.11
Data for Example 2.12

Parameters/Country	Paraguay		Trinidad & Tobago		Denmark
Type of container	(1)	(2)	(3)	(4)	(5)
Vol.cont.(l)	50	100	30.7	48.52	64.8
k (kg/day x °C)	0.0938	0.263	0.155	0.195	0.104
$\bar{T}_e$ (°C)	32	32	31.3	28.3	10
$\bar{T}_f$ (°C)	22	22	25	25	8
V_{si} cm³/kg	1 156.07 (6)	1 156.07 (6)	1 569.9 (7)	2 060.3(6)	1 731(8)
c_{pf} kcal/kg x °C	0.78	0.78	0.78	0.78	0.8
V_{sf} cm³/kg	1 858(9)	1 885(10)	1 466.8(11)	1 466.8(11)	1 274 (12)
t_{MAX} (days)	2	2	2	2	3

Notes:
(1) Styrofoam box
(2) Metallic, styrofoam insulation
(3) Plastic, styrofoam insulation
(4) Rubber, insulated
(5) Metabox 70 (DK)
(6) Tube ice
(7) Crushed ice
(8) Flake ice
(9) *Prochilodus scrofa* (characin)
(10) *Salminus maxillosus* (jaw characin)
(11) Red snapper
(12) White fish

Table 2.12
Results for the Data in Example 2.12

Parameters/Containers	(1)	(2)	(3)	(4)	(5)
t^*_{MAX} (days)	10.67	7.61	4.03	5.60	36.00
n	1.57	1.16	0.71	1.32	6.48

From the results appearing in Table 2.11, it is clear that it is very difficult to generalize regarding a proper fish:ice ratio. Of the cases presented in Table 2.12, only one (case 2) is about the classic option n = 1, in case 3 the option n = 1 will not be enough and, in the other cases n = 1 will be above the specified needs. In extreme cases, it may imply wastage of ice and insulated container capacity.

Although in some modern fishing vessels there are automatic icing devices that can dose ice according to the fish flow, the advice is to look in practice not for the theoretical decimal proportions but for workable proportions (e.g., using gauged buckets or number of shovelfuls) in order to accommodate the amount of ice really needed.

2.4.3 Labour

The engineer can find varying degrees of information, ranging from detailed information on the number of workers required per shift (during production) to the complete absence of data.

There is no quick method that can be universally applied to estimate labour requirements. The method of making estimates based on the sequence of production operations is presented. If a flow-sheet for the process or a chart showing the location of equipment in the factory is available, labour requirements can be estimated.

Table 2.13 shows typical direct labour requirements for the fishery industry, expressed as consumption of man-hours per unit of product.

Table 2.23 shows typical manpower requirements (per unit of finished product) and in supervision, for different fish plants. This Table is placed at the end of this chapter because it also contains information on services requirements for different fish processing plants. For some of the processes, the personnel required for management, administration and supervision, are shown in the third column of Table 2.23.

From the analysis of Table 2.23, it can be deduced that fish canning plants, with mechanical heading and gutting operations, producing more than 30 000 cans of 170 g each daily, require an average of 30 workers per t of finished product. This figure increases to more than 60 workers if there is a substantial decrease in plant capacity whereas, in a completely mechanized process, only 8 workers are required.

In fish freezing plants, the average estimate is about 10 workers per ton of finished product. There is a wide variation in the required number of supervisors, since there are manual and mechanical plants and different levels of technological development (efficient use of manpower and equipment); the highest figure is for manual plants in developing countries. Note should be taken of the low incidence of direct labour in fishmeal plants.

Finally, there is a wide variation in the use of labour per ton of finished product. This depends basically on the type of process used and the capacity of the plant. Totally manual plants, on the other hand, require more than 100 workers which renders large capacity manual fish canning plants non-viable. This short example demonstrates that common sense and experience are necessary to assess labour requirements in practice.

Table 2.13
Typical Direct Labour Requirements in the Fishery Industry

Type of Plant	Work requirements	Reference
Canning		
Argentine Sardines (*Engraulis anchoita*)		
Manual Process	Labour, min/100 cans 170 g	Argentina (Parin *et al.*, 1987b)
Headed and gutted	22 - 30	"
Put in trays and Cooked	9 - 13	"
Packaged	30 - 45	"
Sealed and Boxed	50 - 60	"
Cleaned	3 - 5	"
Other activities	20 - 50	"
Indirect labour	40 - 50	"
Mackerel (*Scombrus japonicus marplatensis*)	Direct Labour, total 2 - 2.25 min/380 g can	"
Bonito (*Sarda sarda*)	Direct Labour, total 2 - 2.25 min/180 g can	"
Hake (*Merluccius merluccius hubbsi*)	Direct Labour, total .8 - 2.1 min/380 g can	Argentina (Parin *et al*, 1986a)
Freezing		
Hake (*Merluccius merluccius hubbsi*)		
Manual sorting	20 - 30 kg/man-min	Argentina (Zugarramurdi, 1981a)
Manual filleting and skinning	40 - 52 kg raw material/man-h	"
Inspection and V Cut	67 - 75 kg fillet/woman-h	"
Packaging (blocks)	81.8 kg/woman-h	"
Bag packaging	30 kg/woman-h	"
Interleaved packaging	54 - 60 kg/woman-h	"
Indirect Labour	1 labourer/10 filleters	"
	1 labourer/5 packagers	"
	1 cold storage attendant/5 t fish for freezing	"
Cod (*Gadus morhua*)		
Gutted (manual)	200 - 240 fish x 3 kg/man-h	Europe, (Vaaland & Piyarat, 1982)
Small size	300 fish/man-h	"
Large size	150 fish/man-h	"
Gutted (mechanical)		
Speed: 25 - 40 fish/min	3 workers/2 machines	"
	Total man-h/t product	
Hake, skinned fillets, whole fish, 5 x 1 kg	91 - 97	Uruguay (Kelsen *et al.*, 1981)
Croaker, H&G (Yield:55%)	55.0	"
Whole croaker (Yield:97%)	23.0	"
Hake fillets, 7.5 kg ea., fatless	110 (*)	"
Hake fillets, 4.5 kg ea., interleaved	112 (*)	"
Hake fillets, with skin, 2.27 kg, interleaved	95	"
Whiting fillets, with skin, IQF (Yield:40%)	105	"
(*) Mechanical filleting		
Salting		
Anchovy (*Engraulis anchoita*)		
Cans "vera carne" (10 kg)	3 cans/woman-h	Argentina (Zugarramurdi, 1981a)
Drum x 250 kg	1 drum/14 woman-h	"

Type of Plant	Work requirements		Reference
Smoking (European style)			
Time (3 workers, 150 kg/load)	Man-h	Hours	Chile (FAO, 1986a)
Reception of raw material	1/2	1/6	"
Washing of raw material	1/2	1/6	"
Filleting and washing	3	1	"
Salting of fillets	3/4	3/4	"
Draining	16	16	"
Smoking	6	6	"
Cooling	1	1	"
Packing	3/4	1/4	"
TOTAL	28.5	25.3	"
Ice making	Consumption of man-h/24 h		
automatic (10 t/24 h)	40		UK (Myers, 1984)
block ice (20 t/24 h)	56		"
automatic (50 t/24 h)	80		"
block ice (50 t/24 h)	136		"
automatic (200 t/24 h)	96		"
block ice (200 t/24 h)	188		"

The low proportion of supervisors found in plants in tropical countries is noteworthy: a more acceptable estimate is one supervisor for every 15-20 workers. The low proportion of supervisors in fish processing plants in developing countries could be linked to the lack of middle level trained personnel, and could be related to the difficulties of some fish processing companies in developing countries, to achieve and keep appropriate fish quality and safety levels. An average estimate for administration can be approximately one employee for every 5-8 direct labour workers. In general, the labour required per unit of production is more or less constant, as has been shown for the medium range (capacity) fish canning industry (Figure 2.5) (Cerbini and Zugarramurdi, 1981a).

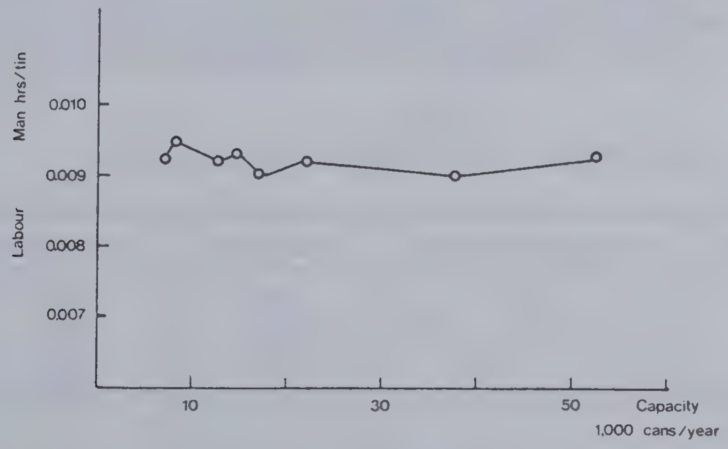


Figure 2.5 Direct Labour Requirements in Fish Canning Plants

The paper on the fish canning industry by Cerbini and Zugarramurdi (1981a) shows manpower requirements lower than those given in Table 2.13; the reason is that the authors analysed plants where the heading and gutting process is mechanical and where cooking was done in a continuous cooker, whereas data in Table 2.13 refer to manual processing plants. Manpower requirements vary with the degree of mechanization and automatization of the plants. Other factors which have an influence on labour productivity and should be considered are: fish size, raw material quality, and workers' training level. In anchovy processing for fish salting poor raw material quality can decrease productivity up to 70%, and proper personnel training can increase productivity in 40% (Montaner *et al.*, 1994b). For instance Figure 2.6 shows the incidence of size and raw material quality in the production of cod fillets with skin.

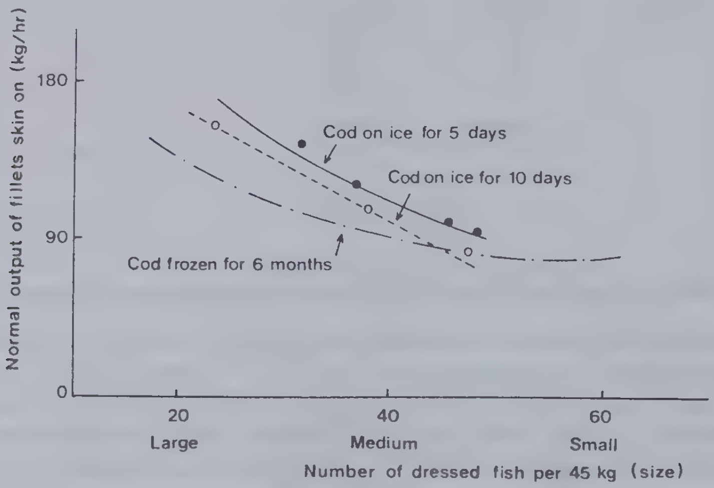


Figure 2.6 Production of Fillets with Skin as a Function of their Size and Quality

Table 2.14 and Figure 2.7 show how yield in the filleting operation varies according to the size of the fish and the experience of the operator (Amaria, 1974). Table 2.15 shows reduction in yield as a result of differences in fresh fish handling (Huss, 1988).

Table 2.14
Fillet Yield by Worker Experience and Size of Fish

Workers	Experience (years)	Mean Size	Mean Yield
2	10	23.9	45.4
3	2	33.9	37.9
4	1	47.8	35.8

Table 2.15
Yield of Fillets made from Gutted Cod

Delay in Icing	Fillet Yield (%)	After Trimming
1.0 h	48.4	43.3
6.5 h	46.5	40.4

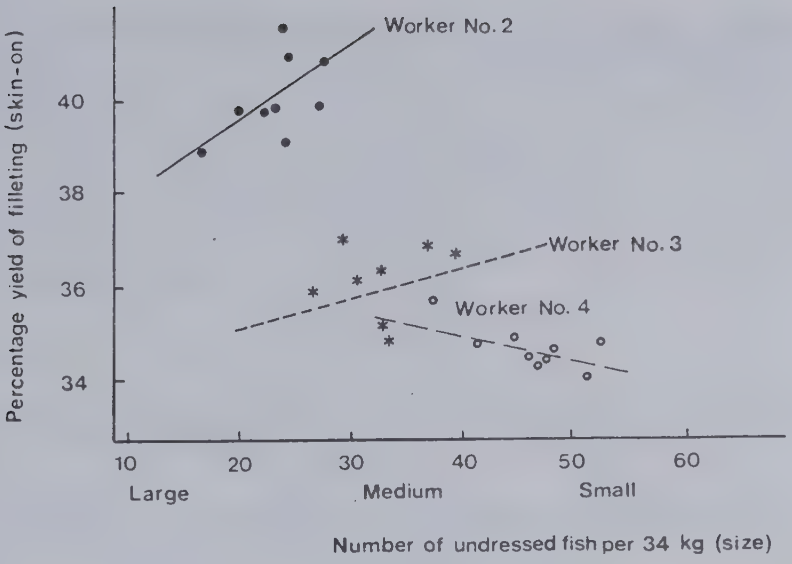


Figure 2.7 Fillet Yield by Size of Fish and Operator Experience

Figure 2.8 shows how the quantity of sardines to be headed and gutted by machine decreases as quality loss increases. However, productivity will be reduced also in manual plants since, to keep a given quality level, sardines have to be sorted by hand after visual inspection. From practical observations the sorting by hand of defective sardines, as is very often performed, is a cumbersome operation that requires a large surface (50-70 m^2/t) and many workers. Quality continues to be lost during selection, and there is the possibility of a high increase in temperature in the fish handled, with an increased risk of histamine formation. Yield after the cooking operation also will be reduced, and a large number of broken sardines will appear in the cans as indication of bad quality. The same reasoning applies to the handling and processing of anchovies and other small pelagics. Quality loss in such cases could be assessed as the percentage of fish with belly-burst.

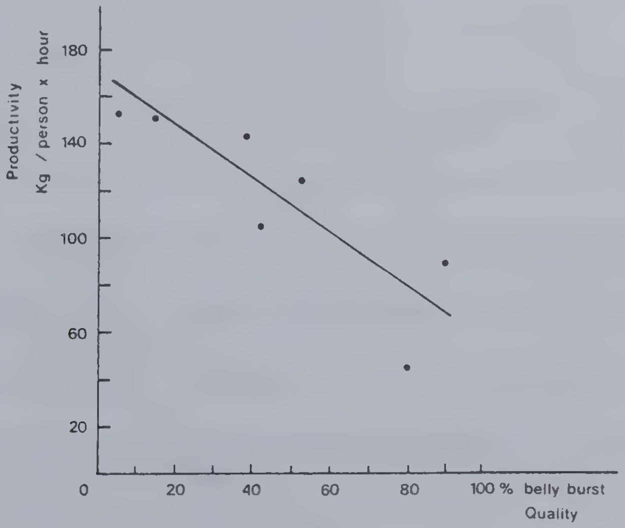


Figure 2.8 Productivity of Heading and Gutting Operation vs Quality of Raw Material
Data from a Mexican cannery (Jensen, 1983)

Figure 2.9 (Amaria, 1974) shows the estimated relationship between yield and filleting performance with and without incentives.

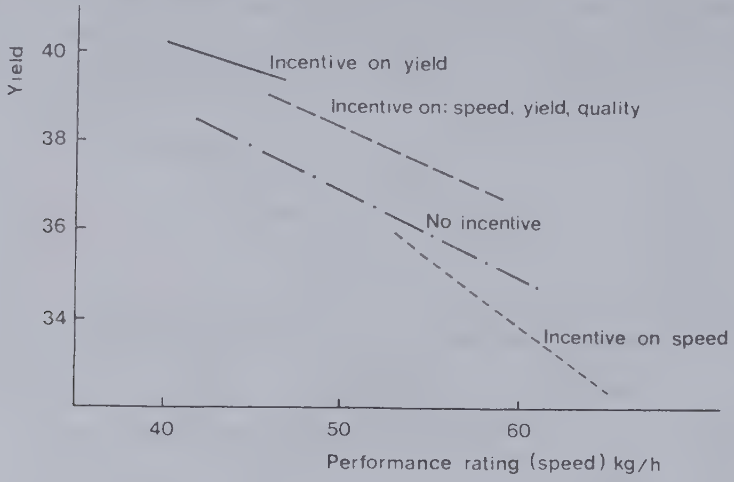


Figure 2.9 Yield vs Performance according to Type of Incentives

It can be concluded that an incentive on performance alone, results in a decrease in yield (from 38 to 34%). Incentives should therefore be given for a combination of performance, yield and quality (Kelsen *et al.*, 1981)

Recent developments in work organization in the fishery industry tend to promote increase of performance, yield and quality through collective incentives (e.g., to the processing line) rather than individual incentives. This type of strategy, applied first in Scandinavian countries (not without initial difficulties) has proved to be successful both for workers and industry. Figure 2.10 shows the relationship between the size of the fish, the fillet yield and filleting performance, skinning and V-cut operation.

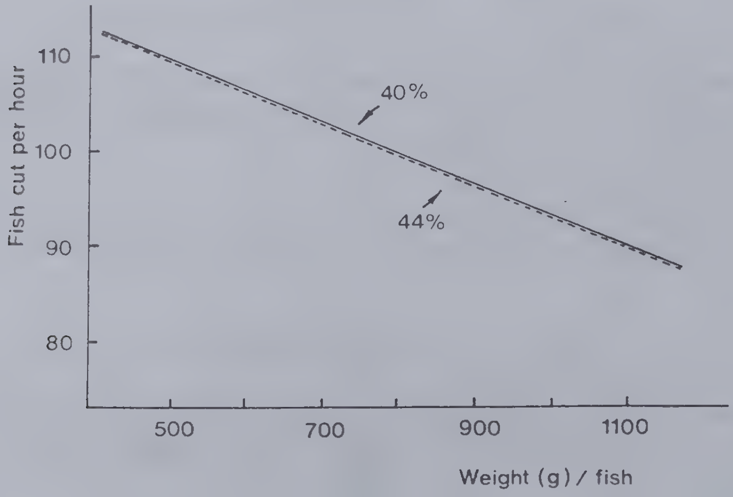


Figure 2.10 Number of Fish, Filleted, V-cut and Skinned vs Weight of Fish (g)

The graph shows that there is no correlation between yield and either the number of fish cut per hour or the size of the fish, which indicates that yield can be improved without affecting the quantity of fish cut per hour. As a result, there are no differences within the 40 to 44% yield range. It should be added that the greater the weight of the raw material, the smaller the quantity of fish that will be cut per hour. If the y-axis were expressed in terms of fish weight cut per hour, its relationship with the size of the fish would be positive, without affecting yield. Therefore it is more costly to use lighter weight fish for this line of production (Kelsen *et al.*, 1981). In actual plants, hake less than 30 cm long is removed from the filleting line and processed as small H&G fish.

Example 2.13 Calculation of Direct Labour

Calculate the number of filleters required to produce 4 t of medium size cod fillet with skin, in a single shift of 8 hours, using cod which has been stored on ice for 5 days.

Answer: From Figure 2.6, for medium size cod fillets of 40 fillets/45 kg (40 fillets/100 lb), production rate will be around 250 fillets with skin/h.

40 fillets/45 kg corresponds to 1.125 kg/fillet

$$\frac{4\,000 \text{ (kg/shift)}}{1.125 \text{ (kg/fillet)}} = 3\,556 \text{ fillet/shift}$$

$$\frac{3\,556 \text{ (fillet/shift)}}{\dfrac{250 \text{ fillet}}{\text{h x filleter}} \text{ x } 8 \text{ (h/shift)}} = 1.778 \text{ filleters, this means 2 filleters}$$

The calculations made from Figure 2.6 pertain to the direct needs of the actual production activity (in this case, the filleting operation exclusively) and do not include the incidence of personnel necessary for moving raw material, finished products, and others. Those values will have to be added to the estimate already made.

Example 2.14 Labour Requirements for a Frozen Fish Plant

Calculate the quantity of labour needed for the frozen fish plant in Example 2.1.

Answer: Worker production rate for each operation can be estimated from Table 2.13.

From Example 2.3 it is known that the plant will handle 5.9 t/day of raw material.

(i) Manual sorting workers (to clean, sort out, re-ice, and distribute fish).

According to Table 2.13, manual sorting can be done at a rate of 20-30 kg raw material/man x hour; the calculation is:

$$\frac{5\,900 \text{ kg/shift}}{20 \text{ (kg/min) x } 60 \text{ min/h x } 8 \text{ h/shift}} = 0.61 \text{ man, say 1 worker}$$

For a plant to start operation, it is convenient to utilize low production rates which should increase with time. From the calculation, one worker would appear to be enough. However, in practice this worker should also unload the trucks, wash the fish, re-ice the fish and clean fish boxes.

Manual cleaning of the fish boxes, corresponding to 5.9 t of raw material (about 200 boxes/day), will take no less than an additional five hours. This means that 2 workers will be needed at this stage.

(ii) Filleters (to fillet and skin the fish manually)

According to Table 2.13, manual filleting and skinning of hake can be done at a rate of 40-52 kg (raw material)/man x hour; the calculation is:

$$\frac{5\,900 \text{ kg/shift}}{\dfrac{40 \text{ kg}}{\text{man x hour}} \text{ x } 8 \,\dfrac{\text{hour}}{\text{shift}}} = 18.43 \text{ men, say 19 filleters}$$

To have an idea of the influence of productivity, the highest rate of production can be considered:

$$\frac{5\,900 \text{ kg/shift}}{\dfrac{52 \text{ kg}}{\text{man x hour}} \text{ x } 8 \,\dfrac{\text{hour}}{\text{shift}}} = 14.18 \text{ men, say 15 filleters}$$

In this case, it is interesting to define a production policy. It is possible to start adopting the lowest production rate, the highest or one in between. In practice, it will depend on the skill of workers found on the work market, work laws, cost of manpower, possibilities to increase production (up to 2 additional tons of raw material, or about 34%), etc.

It should be noted that to take 19 filleters will require four additional positions in the filleting line (additional investment) and maybe additional facilities (e.g., bathrooms) and supervision. A possible compromise is to contract only 15 filleters and pay overtime initially.

(iii) Inspection and V-cut

To determine the number of inspectors (they could actually work as internal quality inspectors) the same considerations can be applied as for the previous point. From Example 2.4 it is known that 5.9 t of raw material produced 2.36 t of untrimmed fillets to go for trimming (inspection and V-cut):

$$\frac{2\,360 \text{ kg/shift}}{\dfrac{67 \text{ kg}}{\text{woman x hour}} \text{ x } 8 \text{ hour/shift}} = 4.40 \text{ women, say 5 inspectors}$$

Probably in this case, it would be advisable to contract five women so as to avoid risks regarding quality (note that in Argentina - from where the data were taken - women are assigned to this type of job because generally they are found to be more careful and tidy than men).

(iv) Packagers

Assuming that fillets will be packaged in blocks to be frozen, from Table 2.13 each packer (woman) will pack 81.8 kg per hour. The calculation is:

$$\frac{2\ 000 \text{ kg/shift}}{\dfrac{81.8 \text{ kg}}{\text{woman x h}} \times \dfrac{8 \text{ hour}}{\text{shift}}} = 3.05 \text{ women, say 3 packers}$$

Please note that bag packaging, interleaved packaging or shatter packaging will give different results.

(v) General (or indirect) workers:

Table 2.13 gives the following figures:

- 10 filleters a general worker, this means 15 filleters 1.54 general workers, say 2 workers
- 5 packagers (or 5 inspectors) a general worker, this means 3 packers plus 4 inspectors (trimming and V cut) will require 2 workers.

In total 4 general (or indirect) workers.

(vi) Freezer attendant

According to Table 2.13, there is the need for one each 5 t of fish for freezing; in this case 2 t, which means that one cold storage attendant will be needed. This example makes it clear that a number of considerations should be made to produce actual calculations of manpower, even if reliable data are available.

The example makes it clear also how some aspects like quality, workers' skill and production policies can affect calculations. A "standard" plant does not exist, and noticeable differences can be found in practice even between similar plants of the same company, particularly when the degree of mechanization is low.

Example 2.15 Labour Requirements for a Fish Canning Plant

Calculate the labour requirements necessary for the canning plant in Example 2.2

Answer: From Table 2.13, average operation time is 2.5 min/can, which when calculated as hours/day is 0.042 h/can. Therefore 14 workers working 8 hours daily will be needed to complete production of 2 670 cans. This includes indirect labour.

2.4.4 Utilities

Generally two values are required to calculate this component:

(a) Specific consumption
(b) Peak consumption

(a) Figures for specific consumption are used as averages in the estimate and represent the average consumption of the service being considered, for a specific capacity of production.

(b) Peak consumption is what can be produced in a case where the entire plant and all the equipment is operating at full capacity or when special equipment, which consumes more than average, is put into operation in the plant.

In fish processing industries, utilities (electricity, steam, water, natural gas and fuels) consumption varies over a wide range, depending on process technology and product characteristics. From the analysis of freezing, canning, cured fish and fishmeal plants, it was found that utilities consumption also depends on plant location (developed and developing countries), equipment characteristics (technology, maintenance and lifespan) and the source of the utilities (Montaner *et al.*, 1994c). In Table 2.23 (at the end of the chapter) data on the consumption of these services are shown for different fish processing plants.

2.4.4.1 Electricity

Electricity is used in two different ways:

(a) for processes and lighting of the plant;
(b) other uses: lighting the perimeters, administrative buildings, etc.

Consumption of electricity can be divided into two parts. At full production, a part (lighting, air conditioning of offices, etc.) approximately 20% of the total is practically constant and independent of production. The remaining 80% depends on production on a non-linear basis. Energy consumption levels, as shown in Tables 2.16, 2.17 and 2.23, are also indicative and show variations which can be caused. For example, the consumption of electricity by the same type of freezer will obviously be greater in a tropical climate than in a temperate or cold one. This consumption can be reduced if walls and pipes are insulated, which will in turn increase fixed costs (set conditions exist for maximum thickness of insulation). Some equipment manufacturers produce "tropical" designs, which, besides being more insulated, have additional filters for air and fuel oil, more resistant materials at critical points and a higher or lower level of automation.

In practice, actual energy consumption, of any type, depends on the type of technology used and on the efficiency with which it is used. In developing countries, where the specialized labour for operation and maintenance is scarce or not properly trained, or where equipment must continue to be used well past its useful life because there is no capital for replacement, it is not difficult to find cases of energy consumption much higher than should be obtained from the initial characteristics and specifications of the equipment.

A typical case is that of ice production. In standard tropical conditions, the energy required to produce 1 t of ice varies between 50 and 90 kWh (see Table 2.23), where the lower value is for tube ice and the higher for flake ice. In a study carried out on four ice-making plants in Tanzania, the following values were found: 86, 117, 136 and 178 kWh, the lower value for block ice and the rest for flake ice plants. The energy requirements for the plants was therefore 40-110% higher than what could be expected. Problems, such as malfunction of pumps and fans, were identified in these plants (Anon., 1990).

The worldwide tendency it is to reduce and optimize the use of energy. Whereas in the past Governments were inclined to subsidize energy consumption to promote industry, in the future energy inefficient industries will be in practice penalized. This is not only due to the possible lack of oil, but also to the fact that reduction in oil consumption will reduce pollution. The fishery industry of developed countries, in particular those that lack oil (e.g., Iceland, Japan), have already started programmes to optimize energy consumption. Developing countries that should import oil (and use for that valuable hard currency) should become more concerned about energy consumption.

From the analysis of Table 2.23, it seems reasonable to extrapolate the consumption of electricity for canning plants to a value of 0.05 kWh/can of 170 g. Similarly, an average value of 200 kWh/t of finished product can be used for frozen fish plants and 140 kWh/t for fishmeal plants equipped with a unit to concentrate stickwater while for fishmeal plants without a concentration unit, this value decreases to 120 kWh/t of finished product.

In addition to the values of Table 2.23, Table 2.16 presents average values of energy consumption (electricity and fuels) in the New Zealand fishery and food industry.

Table 2.16
Energy Use in Fishery and Food Manufacturing Industry in New Zealand (1981)
Data expressed as kWh of purchased energy per 1 kg of finished product
(Cleland *et al.*, 1981) (1)

Product type	Fuels		Electricity		Total
	Direct use in processing	Allocated baseload	Direct use in processing	Allocated baseload	
Frozen whole fish and fillets	0	0.222	0.175	0.722 (2)	1.111
Processed fish products (3)	0.777	0.555	0.305	0.583 (2)	2.222
Fishmeal	3.361	0.333	0.361	0.055	4.111
Frozen poultry	0.169	0.061	0.169	0.194	0.583
Frozen vegetables	0.472	0.447	0.225	0.508	1.666
Processed meats (4)	-	0.972 (2)	-	0.277 (5)	1.25

Notes:

(1) Data do not include intra-factory transportation. No distinction is made between boiler fuel and fuel used in direct-fired equipment.

(2) Includes energy used in refrigerated storage at the factory after processing but before distribution.
(3) Average for canned fish, smoked fish fillets and battered, reformed fishery products.
(4) Data represent the majority of the industry but are not representative of the industry as a whole.
(5) Insufficient data existed to divide into direct use in processing and allotted baseload.

If available, natural gas can be utilized instead of fuel oil. At the same time, according to the technology utilized and the cost of the different sources of energy, the proportion between the different types can vary. In Table 2.17, data on energy consumption (electricity plus gas) of an American fish processing company are presented.

Table 2.17
Annual Energy Consumption (gas and electricity) 1981-83 Production Rate and Energy Consumption per 1 kg of Finished Product for a Fresh and Frozen Fish Processing Plant in the USA (adapted from Enriquez *et al.*, 1986)

Element	1981	1982	1983
Natural gas use (1)	164 237.6 (21.6%) (4)	150 580.4 (21.7%) (4)	168 838.8 (20.1%)(4)
Electrical energy use (1)	608 124.4 (78.4%) (4)	540 923 (78.3%) (4)	670 285 (79.9%)(4)
Total energy use (1)	772 362	691 503.4	839 123.8
Total product output (2)	567 806.9	632 652.3	702 024.9
Energy consumption per 1 kg of final product (3)	1.360	1.093	1.195

Notes: (1) in kWh; (2) in kg; (3) kWh/kg (final product); (4) % of total energy consumption

2.4.4.2 Fuels and steam

It is also necessary to know the fuels and steam consumption of the process. This is usually given by the equipment manufacturers. However, consumption may be different in practice. Steam consumption can basically be divided into three groups:

- Steam for processes
- Steam for electricity generation
- Steam for other uses (heating, laboratories, cleaning)

Tables 2.16 and 2.23 show the consumption of fuels in general and fuel oil necessary to supply steam to processing plants. The ratio used in technical estimates is between 14 and 22 kg of steam/kg of fuel oil (Lisac, 1974; Vaaland and Piyarat, 1982).

For fish canning plants, the maximum value can be estimated at 0.05 kg fuel oil/170 g can, although it should be pointed out that the figure resulting from calculating only the thermal treatment parameters can cut this value by half. For fishmeal plants, a consumption of 140 to 190 kg fuel-oil per ton of finished product can be estimated, depending on the existence or not of a concentration unit.

2.4.4.3 Water

Water can be used for different purposes in a plant. The following uses could be considered:

- Processing water
- Refrigeration water
- Boiler water
- Water for general and human use

Each type of water may require special treatment. Sources of water for a factory are usually:

- Well water
- Surface water (river, lake, etc.) or sea water
- Tap water

In the fish processing industry, operations can vary from one plant to another, but the quantity and quality of water used in a similar process are the same and depend directly on the capacity of the plant. Current tendency is towards design of fish washing machines functioning with reduced amounts of water; this is part of the "clean production" approach. By achieving appropriate washing with less water, the overall water requirement is reduced and so is the amount of liquid wastes (reduction in the installed capacity and cost of liquid waste treatment). Table 2.18 lists percentage of water requirements for the production of frozen white fish fillets.

Table 2.18
Percentage of Water Used in Different Operations in the Production of Frozen White Fish Fillets in Canada (Blackwood, 1978)

Operation	Total water consumption (%)
Water transport of fish fillets and waste	50 - 65
Cleaning, scaling of fish, preparation of fillets, and skinning	15 - 25
Cleaning of plant, boat, wharf, etc.	12 - 18
Manufacture of fishmeal	2 - 4
Manufacture of ice	1 - 3
Fresh water for fishing boats	1 - 2
Baths and sinks	1 - 2
Water for boilers, refrigeration, etc.	1 - 2

Manual fish washing is done usually in large bats (made out of concrete, stainless steel or plastic); shallow baths (about 0.5 m deep) allow better washing. Washing procedure can be batch type for both water and fish or batch-wise for fish and with a water overflow. Water requirements are in the order of 0.5-1 m^3/t of fish to be washed. As water requirements for washing are proportional to the surface to wash, small pelagics will require more water than medium size and large fish per ton of fish to be washed.

Plenty of water is required in fish and fish fillet washing. Table 2.18 shows water consumption for seven different fish washing machines. Table 2.19 also shows the influence of different types of technological alternatives on water consumption during fish washing.

Table 2.19

Water Consumption in Fish and Fish Fillet Washing Machines

Type of machine	Machine capacity (t/h)	Water consumption	Water consumption per ton of fish (m^3/t fish)	Reference
Herring washer (1)	2	4/6 m^3/h	2-3	Baader 654 (7)
Raw fish washer (2)	5-6	15/20 "	2.5-4	Baader 670 (7)
Fish washer (3)	3	0.6 m^3 (5)	-	Baader 679 (7)
Washing, de-bleeding and brining drum (3)	2	0.3 m^3 (5)	-	Baader 676 (7)
Standard drum washer (4)	-	-	1	Blackwood (1978)
Washing bat	0.53.5 (6)	0.6 m^3/h	1.2-0.17 (6)	Model MK5 (8)
Washing bat	1.5-10 (6)	0.6 m^3/h	0.4-0.06 (6)	Model MK 8 (8)

Notes:

(1) Batch washer
(2) Continuous washer
(3) Continuous washer, however, part of water is retained (overflow)
(4) Standard drum washer (see design in Blackwood, 1978)
(5) This is only the initial charge of tub, overflow should be added
(6) Capacity depends on fish residence time in the washer (adjustable from 3 to 20 min)
(7) Data taken or calculated from Baader catalogue (English version) for 1988
(8) Data taken or calculated from K.M. Fish Machinery A/S (DK) Catalogue for 1994

Fish processing also requires large amounts of water. Table 2.19 presents data on water requirements for some machine fish-processing operations. A completely mechanized white fish fillet processing line will require, according to Tables 2.19 and 2.20, 4.5-6 m^3 of processing water per ton of fillets produced. Actual water consumption should be calculated according to machine specifications, characteristics of fish to process and worker skills.

Fish, fillets and shrimps can be transported within a processing line by conveyors (dry method) or by a flow of water (wet method). The wet method requires very large amounts of water as can be seen from Table 2.23 (Blackwood, 1978). The amount of water required for hydraulic conveyors depends on the fish size; small sized fish require 3-4 m^3/t, medium sized fish 4-6 m^3/t and large sized fish 6-8 m^3/t (Chupakhin and Dormenko, 1965).

Not all water has to be drinking water; much of it, depends on its use (e.g., fish washing and hydraulic transport) can be clean seawater. Of the very large values reported by Blackwood (1978) on water consumption in the Canadian fishery industry (see Table 2.18) most of them (between 98.5 and 95%) correspond to clean seawater. However, today, the tendency is to reduce this large amount of clean seawater because it can easily become a source of pollution (harbours, bays and rivers) and increase waste treatment costs.

Table 2.20
Water Requirements of Some Fish Processing Machines

Type of machine	Machine capacity (No. of fish/min) (1)	Machine capacity (t/h)	Water consumption (m^3/t) (1)	Water consumption per t processed (m^3/t)	References
Grading (shrimp)	-	0.5 (1)	1.5	3	Model KM500 (5)
Grading (shrimp)	-	1 (1)	1.5	1.5	Model KM1000 (5)
Grading (small pelagics)	-	15 (herring)(1)	2.1	0.14	Model KM231 (5)
Grading (white fish)	-	up to 18 (1)	1.2	0.06	Baader 486 (6)
Gutting (white fish)	25-40	3.5 (2)	1.5	0.43	Baader 160, 161, 162 (6)
Gutting (white fish)	40-60	5 (2)	1.8	0.36	Mark 5 (5)
Nobbing (small pelagics)	460	0.6 (2)	0.9	1.5	Baader 464 (6)
Filleting	24-34	1.5 (2) (3)	0.9	0.6	Baader 189 (6)
Filleting	40-65	1.8 (2) (3) (4)	2.4	1.33	Baader 190(6)
Skinning	30/140	1 (2) (3)	0.09	0.09	Baader 51 (6)

Notes:
(1) According to manufacturers data
(2) Calculated from manufacturers data and average data on processed fish species. Capacity can change according to actual fish size and operator skill
(3) Result expressed in t/h of fillets produced
(4) In this case, the machine produces V cut fillets
(5) Data taken from K.M. Fish Machinery A/S (DK), catalogue for 1994
(6) Data taken from Baader catalogue (English version) for 1988

Example 2.16 Services Requirements for a Frozen Fish Plant

Estimate consumption of water and energy for the frozen fish plant in Example 2.1.

Answer: Values can be estimated from Tables 2.16 and 2.23.

Energy consumption. Total energy consumption can be estimated as 1.111 kWh/kg finished product (see Tables 2.16 and 2.17); i.e., for 2 t of final product, the total energy required for processing and refrigerated storage before distribution will be 2 222 kWh. Of this total, around 80% (Tables 2.16 and 2.17), 1 776 kWh, will correspond to electricity and the remaining 20% (444 kWh) should be provided by fuels (fuel oil or gas or a mixture of both). The energy consumption directly related to production can be calculated in order to obtain the component of the production cost. From Table 2.23 the average value is 200 kWh/t of finished product; therefore 400 kWh will be required daily to produce 2 t of fillets.

Water consumption. In this case, gutting, filleting and skinning will be done by hand; from the data provided by Zugarramurdi (1981a) (see Table 2.23), 4 m^3 for direct fish processing will be enough. Assuming fish is washed in a standard drum washer, 5.9 m^3 should be added for 5.9 t of raw material, which means a total of 9.9 m^3 for fish processing only. Taking into account Table 2.18 and that, in this case, it is dry processing, the rest of water (cleaning of plant and boxes, baths and sinks and water for boiler and refrigeration) will be around 47-49% of total water requirements; this means an additional 9.14 m^3. In total (9.9 m^3 + 9.14 m^3) 19.04 m^3 of water are required for 2 t of fillets. The lowest figure of Blackwood (1978) data (see Table 2.23) would be 28 m^3, which is a much higher value (47% above). In this case, the estimate of 19 m^3 seems acceptable. This example clarifies the need to determine directly whenever possible, water consumption. As observed by Blackwood (1978) wide differences are found in water consumption and it is an indication of water wastage.

Example 2.17 Services Requirements for a Fish Canning Plant

Calculate the consumption of water, electricity and fuel for the canning plant in Example 2.2. Daily production is 2 670 cans of tuna of 180 g each.

Answer: According to initial data, the plant will produce 2 670 tuna cans per day of 180 g each, i.e, daily production will be 0.4806 t (in this case, fish and oil together are considered "product"). Table 2.21 can be constructed from data in Tables 2.16 and 2.23:

Table 2.21
Energy and Water Consumption in a Fish Canning Plant

Reference	Electricity	Fuels	Total energy	Water
Table 2.23 (1)	122 kWh/day	1 643 kWh/day (4)	1 787 kWh/day	34 m^3/day
	0.054 kWh/can	0.615 kWh/can	0.670 kWh/can	12.7 l/can
Table 2.23 (2)	21 kWh/day	552 kWh/day (4)	573 kWh/day	13.5 m^3/day
	0.008 kWh/can	0.21 kWh/can	0.218 kWh/can	5 l/can
Table 2.16 (3)	641 kWh/day	427 kWh/day	1 068 kWh/day	-
	0.240 kWh/can	0.160 kWh/can	0.4 kWh/can	-

Notes: (1) Data from Myrseth (1985) on tuna canning (automatic processing line).
(2) Data from Edwards (1981) on sardine canning in tropical countries (manual processing).
(3) Data from Cleland *et al.* (1981) processed fishery products in general (including energy used in refrigerated storage).
(4) Conversion factor: 11.955 kWh per 1 kg of fuel oil.

Table 2.21 allows us to make the following analysis:

(i) Total energy consumption will be in the order of 573-1 787 kWh/day, and 0.218-0.67 kWh/can.

(ii) Water consumption will be in the order of 5-12.7 l/can.

(iii) Fuel oil consumption will, in this case, be more important than electricity consumption, between 92 and 96% of the total.

(iv) Edwards' (1981) data differ from Myrseth's (1985) data by 68% regarding total energy consumption and 60% regarding water consumption. The large difference in values could be due to the large degree in mechanization and automation in the Norwegian plant considered by Myrseth (1985).

In conclusion, an average of the data of Edwards (1981) and Myrseth (1985) can be adopted as the best estimate in this case. This example also shows that any application of data from Table 2.23 (or in any other table) should be carefully analysed during calculations and cross references checked whenever possible.

2.4.5 Packaging

Packaging is usually considered within the raw material inputs. However, it was decided to discuss it separately because in some cases in the fishery industry it can represent a large percentage of total production costs. Table 2.22 shows the consumption of packaging materials for different products.

Table 2.22
Packaging Requirements in the Fishery Industry

Type of Packaging	Packaging Requirements	References
Frozen*		
Interleaved fillets	15 kg polyethylene/t product	
Waxed cartons, 7 kg each	150 boxes/t product	
Master cardboard boxes, 21 kg each	50 boxes/t product	
Straps	1 kg/t product	
Labels	50 labels/t product	
Canned*		
Thermoplastic Packaging	36 cans x 115 g 36 cans x 170 g 24 cans x 260 g	
Corrugated cardboard box	1 box/24 cans x 380 g	
Fishmeal		
Bags (50 kg/bag)	22 bags/t fishmeal	(Shaw, 1976)
Salted		
Drums x 50 l	17.6/t fresh fish	(Perovic, 1990)
Smoked (240 fish at 500-600 g ea.)		
Trays	120	(FAO, 1986a)
Self-sticking tape	48 m	"
Labels	120	"

* Standard consumption in Argentina

Example 2.18 Packaging Requirements for a Frozen Fish Plant

Calculate the packaging requirements for the daily production of the frozen fish plant in Example 2.1. Daily production is 2 t of frozen fish blocks.

Answer: Daily consumption of packaging can be calculated from the values of Table 2.22.

- 300 waxed cartons
- 100 master cardboard boxes
- 2 kg straps
- 100 labels

Example 2.19 Packaging Requirements for a Fish Canning Plant

Calculate the packaging requirements for the canning plant in Example 2.2.

Answer: The following values are obtained from the data given in Tables 2.2 and 2.22 :

- 2 670 cans of 180 g each
- 115 corrugated cardboard boxes x 24 cans

In this section, several references illustrate the relationship between yield, inputs and quality. Today, it is felt that the task of quality assurance also includes analysis and control of yield and inputs for a plant (Huss, 1992). This concept, which in practice is significantly different from the classic concepts of fish inspection and quality control, is justified by the fact that quality assurance requires a more detailed, rational and dynamic knowledge of the processes. This in turn involves the analysis and control of yield, inputs, work conditions and safety (which influences the work force) and reduction of losses and/or all types of waste. This information is in turn linked to costs, to be analysed in Chapter 4.

Table 2.23
Manpower and Services Consumption for Fish Plants

Type of Plant/Capacity (t of RM/time)	Direct Manpower (No. workers/t FP)	S,A (1)	Water (m^3/t FP)	Electricity (kWh/t FP)	Fuel-oil (kg/t FP)	Data calculated from
Canning Plant						
2/day (Manual H&G)	112	n/a	375/day	n/a	n/a	Shaw, 1976 (Tropical Countries)
2/day (Mechanical H&G)	62	-	-	-	-	"
20-30/day (Mechanical H&G)	30	S: 1/20	n/a	n/a	n/a	"
Sardines n/a	-	-	-	25	90	Lisac, 1974
Sardines: 2/day (Mechanical H&G)	82.5	S: 1/33; A: 1/22	28	59	96	Edwards *et al.*, 1981 (Tropical Countries)
Sardines: 2/day (Manual H&G)	140	S: 1/56; A: 1/37	28	44	96	"
Sardines: 17/day (Mechanical H&G)	31	S:1/20	n/a	294	294	Zugarramurdi, 1981b (Argentina)
Sardines: 15/8 h (Mechanical H&G & Packaging)	8	S: 1/15; A: 1/5	57	226	174	Myrseth, 1985 (Norway)
Smoked Sardines: 5/8 h	20	S: 1/13; A: 1/6	74	308	147	"
Tuna: 20/8 h (Automatic production line)	9	S: 1/18; A: 1/8	71	300	286	"
Skipjack: 10/8 h "	9	S: 1/9; A: 1/7	62	489	221	"
Salmon: 8/8 h "	n/a	n/a	52	196	204	"
Shrimp: 3.6/8 h "	n/a	n/a	206 (2)	580	237	"
Fish Freezing Plants						
2/day	25-31	n/a	36	n/a	n/a	Shaw, 1976 (Tropical Countries)
20/day	10-12	n/a	n/a	n/a	n/a	"
Shrimp: 4/8 h.processing	5	S: 1/10	240	200	n/a	Bartholomai, 1987 (USA)
Shrimp: 1.6/day	51	S: 1/8	1.3	1 111	n/a	Street *et al.*, 1986 (Tropical) Countries)
Whole fish 4.48 t FP/8 h	4	S: 1/6	1.2	446	n/a	"
Catfish: 26/8 h (6)	2	S: 1/28	14.4	105 (7)	n/a	Bartholomai, 1987 (USA)
Hake fillet: 25/day	9 (13)	S: 1/20	2 (12)	588	n/a	Zugarramurdi, 1981a (Argentina)
Whole and filleted fish	n/a	n/a	n/a	897	n/a	Cleland *et al.*, 1981 (New Zealand)
Croaker (H&G)	7	n/a	n/a	n/a	n/a	Kelsen *et al.*, 1981 (Uruguay)
Whole croaker	3	n/a	n/a	n/a	n/a	"
Hake and whiting fillets	11-13	n/a	n/a	n/a	n/a	"
White fish fillets (dry transport)	n/a	n/a	14-32	n/a	n/a	Blackwood, 1978 (Canada)
White fish fillets (wet transport)	n/a	n/a	83-275 (2)	n/a	n/a	"

Type of Plant/Capacity (t of RM/time)	Direct Manpower (No. workers/t FP)	S,A (1)	Water (m^3/t FP)	Electricity (kWh/t FP)	Fuel-oil (kg/t FP)	Data calculated from
Cold Storage						
10 t fresh fish/24 h	n/a	n/a	n/a	0.5	n/a	Lisac, 1974
10 t frozen fish/24 h	n/a	n/a	n/a	1	n/a	"
Ice Production						
Ice	n/a	n/a	n/a	50-90	n/a	Lisac, 1974
Tube/flake ice (Temperate Zone)	n/a	n/a	n/a	45-60	n/a	Myers, 1984
Tube/flake ice (Tropical Zone)	n/a	n/a	n/a	60-85	n/a	"
Fishmeal Plants						
n/a	n/a	n/a	n/a	175	200 kg	Lisac, 1974
20/8 h	1	n/a	n/a	n/a	n/a	Shaw, 1976 (Tropical Countries)
200/8 h	0.3	n/a	n/a	n/a	n/a	"
10-60/24 h (8)	1	n/a	90	120	140	FAO, 1986c
100-200/24 h (8)	0.6	S: 1/7	62	112	136	"
250-500/24 h (8)	0.3	S: 1/8	50	104	132	"
10-60/24 h (9)	n/a	n/a	126	140	220	"
100-200/24 h (9)	n/a	n/a	90	132	192	"
250-500/24 h (9)	n/a	n/a	73	124	180	"
Salted						
Anchovy: 1 000/day	23 (10)	n/a	14	35	n/a	Perovic, 1990 (Mexico)
Dried						
Mechanical: 0.654/12 h	23	n/a	n/a	170	395 (11)	Waterman, 1977 (African Countries)
Manual: 0.654/12 h	47	n/a	n/a	n/a	n/a	"
Protein Concentrate						
FPC, type A: 200/day	0.15	n/a	49	230	53	Almenas *et al.*, 1972
FPC, type B: 56..8/day	1.8	n/a	n/a	223	223	Vaaland & Piyarat, 1982 (Brazil)
Silage: 6 t FP/day	0.33	n/a	n/a	n/a	n/a	Bertullo, 1989 (Uruguay)

Type of Plant/Capacity (t of RM/time)	Direct Manpower (No. workers/t FP)	S,A (1)	Water (m^3/t FP)	Electricity (kWh/t FP)	Fuel-oil (kg/t FP)	Data calculated from
Smoked						
Small Fish (dried/smoked) 4.3/day	13	1/6	n/a	2.6 m wood	n/a	Waterman, 1977 (Tropical Countries)
Marine Beef						
Mechanical Processing: 120/day	3	n/a	15.9	2.493/t FP	n/a	Vaaland & Piyarat, 1982 (Brazil)
Marinated						
Herring	n/a	n/a	21	n/a	n/a	Blackwood, 1978 (Canada)

RM: Raw Material
DM: Direct Manpower
FP: Finished Product
H&G: Headed and Gutted

Notes:

(1) S: No. of Supervisors/No. of Workers; A: No. of Administrative/No. of Workers
(2) The raw material is transported by flowing water and gravity
(3) Assuming a raw material yield of 40%
(4) Manual packaging (rest mechanized), with shrimp being moved by water
(5) With ice plant, RM and FP cold storage
(6) Three types of product are made: H&G, fillets and fish balls
(7) Note, the refrigeration equipment consumes 1.3 t CO_2/t FP
(8) With indirect steam drier, without evaporation plant. Compact line
(9) With indirect steam drier, with evaporation plant
(10) Final salted product: 915 t
(11) Diesel Oil
(12) Only fish processing consumption (it does not include washing)
(13) Overtime was part of the production scheme

3. CAPITAL INVESTMENT COSTS

3.1 Introduction

When analysing a project to build a new fish processing plant, expanding or renovating an old one, or changing an existing process or line, the primary and most important decision regards the various investment possibilities and, eventually, deciding whether or not to invest.

Decisions on investments are based on the profit and sustainability of the technical alternative chosen and on the capital available or borrowed. Variables affecting profit and sustainability are manifold and usually fall into three general interrelated groups: market, investment and costs.

Market analysis will help to establish the probable amount of fishery products to be sold, and this information will help determine the minimum plant capacity. In turn, plant capacity is directly related to investment and this influences the cost of production. As a general principle, all feasibility studies are based on an early market survey which will provide the answers to the following questions:

1. How much can be sold? (With a minimum of 5 years projection from the anticipated start-up date of industrial activities)

2. At what price should the product be sold?

The capacity of the project can be determined from the above and studies can then be undertaken which will allow a decision to be made on whether or not to invest. In the case of existing plants, investment analysis is necessary to determine the fixed costs of each product; in turn, knowledge of the capital costs of the main equipment is useful in technical and economic studies of repairs and/or replacements.

3.1.1 Definitions

The total amount of money necessary to put a project into operation is known as "Capital investment costs". This investment can be made through in-house capital, credit from national and international financing agencies, and from suppliers. The total capital required to complete and operate the project is composed of two parts:

1) FIXED CAPITAL (I_F) which is the amount of money necessary to completely construct a processing plant with auxiliary services, and to bring it to the point of start-up production. It is basically the total value of all the assets of the plant.

Fixed assets can be tangible or intangible. Tangible assets comprise machinery (including the cost of assembly), buildings, auxiliary installations, etc., and the intangible assets include patents, technical knowledge, administration expenses, operation, start-up costs, etc.

2) WORKING CAPITAL (I_W) which includes the capital resources necessary for the plant to operate at the levels forecasted in the technical and economic studies, once it has been installed and normal operations begin.

The amount of this capital varies within very wide limits, depending on the market for which the products are intended, the characteristics of the process and the conditions established by the source and availability of raw materials.

3.2 Fixed Investment

Fixed capital is usually divided into the following components:

A. Direct Costs

(1) Pre-project study and analysis expenses
(2) Main equipment
(3) Equipment installation
(4) Piping (installed)
(5) Instrumentation and control
(6) Electrical installation
(7) Construction (including services)
(8) Auxiliary services
(9) Land and land improvement
(10) Starting-up costs
(11) Interest during construction

B. Indirect Costs

(12) Engineering and Supervision
(13) Construction expenses
(14) Contractor fees
(15) Contingencies

Each of these components can be estimated separately, and its magnitude will vary considerably according to the nature of the project. These components of fixed investment are briefly described below.

A. Direct Costs

3.2.1 Pre-project study and analysis expenses

Preliminary economic studies are usually performed before deciding on or supporting construction of a project; these include investigative travel, market surveys, laboratory and pilot plant studies, etc. However, the procedure for charging these costs varies from project to project.

In the case of public utility projects, for example, the Government does not usually add these expenditures to the total costs of the project and regards them as unrecoverable promotion costs. All the resources assigned to a project must be considered as part of its cost, including those incurred at the research stage and pre-project costs.

3.2.2 Main equipment

In some cases, the pro-forma invoices of the equipment only include their intrinsic value, and in others, the value of the equipment after installation. Where it includes the value of the installed equipment, components (2) and (3) can be calculated together and include all complementary installations. Where equipment or materials have to be imported, details will be given in terms of FOB (equipment price at port of origin), CIF (price including freight and insurance) and at the utilization site (import expenses, freight, etc.).

The equipment and machinery used during the assembly and which can be used in the production process must also be included. The value can be found by depreciating the goods according to use, incorporating only the resulting residual value (see the concept of depreciation and residual value in Chapter 4).

3.2.3 Equipment installation

If this component is dealt with separately, provision must be included for installation of imported equipment. The cost of installation will often include payment of qualified expatriate personnel. This is convenient for the experience that the personnel of the supplier company should have, and because, in many cases, equipment suppliers will only honour their guarantees if the equipment is assembled, adjusted and started-up by their own personnel or by technicians authorized by them.

When no other values are available, 20% of total equipment cost may be used in order to estimate installation cost.

3.2.4 Piping (installed)

In many estimating methods, this component is calculated separately from the rest of the equipment. In a detailed estimate, calculation of the cost of pipes is made with a diagram of the pipes and their siting. Piping costs can vary greatly in the fishery industry, from low to relatively high values.

Piping in the fishery industry is utilized, for instance, for the purpose of conducting water (fresh and sea water), brine, refrigerants (e.g., ammonia), compressed air, sewage and liquid effluents, hydraulic fish transport, steam, edible oils, sauces and special gases (e.g., CO_2 or mixtures for MAP - modified atmosphere packaging).

3.2.5 Instrumentation and control

This component includes all auxiliary equipment and instruments for controlling and recording the different variables at each stage of the process; it will increase with the application of HACCP and HACCP-based methods in the fishery industry.

3.2.6 Electrical installation

The costs involved in electrical installations consist mainly of labour and materials necessary for supplying power and lighting to the process, while the costs for illuminating the service buildings are normally included in the cost of auxiliary services.

3.2.7 Construction (including services)

Cost of construction includes the expenditure on labour, materials, and supplies needed for the construction of all buildings connected to the plant. They include plumbing costs, electrical installation, ventilation, air conditioning, and similar building services. The cost of constructing a fish plant usually varies according to the country and the site of the plant.

Table 3.1 shows international values for the cost of construction according to country and type of process. When no other data are available building requirements can be estimated at 150 m^2 per ton of raw material daily processed.

Table 3.1
Cost of Construction of Fish Plants

Type	US\$/m^2	Country	References
Fish Plants	200-250 100-150	Argentina Brazil	Vaaland & Piyarat, 1982
Building for Freezing	97.8	Tropical Countries	Street *et al.*, 1980
Buildings for fish production first category, with offices, buildings for storage sinks, etc.	250-350	UK	Myers, 1984
Construction with sinks and a few offices	150-250	UK	Myers, 1984
Sheds and other types of open simple buildings	100-150	UK	Myers, 1984
Dry processing, building	75	African Countries	Waterman, 1977
Canning building	80-100	Indonesia	Bromiley *et al.*, 1973
Type, Capacity	US\$ '000	Country	References
Fish plants		Tropical Countries	Shaw, 1976
1-5 t raw material/day	30-60		
6-20 t raw material/day	40-90		
21-50 t raw material/day	65-190		
51-100 t raw material/day	100-240		

3.2.8 Auxiliary services

The accepted definition for auxiliary services for a process are the structures, equipment and services not directly involved in the process. Normally, these include equipment for the supply of steam, water, electricity, compressed air and fuel. Some of these services can be bought from other companies, in which case they are considered part of production costs and are not included in investment calculations. Waste disposal equipment, fire extinguishers, cafeteria, etc., are also usually included in the cost for services.

3.2.9 Land

The cost of the land depends on its location and can vary by a 30-50% cost factor between a rural area and a highly industrialized one. The value of land does not decrease with time and is therefore not included in fixed investment when annual cost of depreciation is calculated. Although land does involve capital investment, it is usually preferred to include in fixed capital only those items for which depreciation is allowed by law, thus excluding land. In average, land costs for industrial plants amount to 4-8% of the purchased equipment cost or 1-2% of total capital investment (Peters and Timmerhaus, 1978).

3.2.9.1 Land improvement

The part of the investment which is used for land improvement includes the cost of materials for fences, levelling of the land, roads, parking, and other similar costs.

3.2.10 Starting-up costs

There is a period between formal completion of construction and commencement of normal production, "starting-up", and which can last from a few weeks to several months. Obviously, a series of costs are incurred during this period. They can be divided into two main groups.

- Construction costs during starting-up (loss on production lines and equipment, flaws in design to be solved, malfunction of equipment, need for additional equipment, etc.)
- Starting-up operational costs (salaries, raw materials, semi-finished or finished products falling outside specifications, etc.)

While the first are always included as fixed capital and as such, depreciate during the plant's useful life, there is no single criterion for the second. Depending on the accounting philosophy of the business, they can also be capitalized, or considered abnormal operational costs and charged to the losses component. Although in this last instance they are not considered in the economic evaluation of the project. However, the general tendency is to reduce starting-up costs as much as possible, by prevention at design stage.

3.2.11 Interest during construction

Generally, two situations can be established: a) when the capital required for the development of the project is one's own, or b) when some of the funds come from external sources (bank credit). In the latter instance, the interest is compounded from the moment the credit is received until the completion of construction. This interest will be added to the loan, and the total will make up the investment component.

B. Indirect Costs

3.2.12 Engineering and supervision

These expenses include not only payment for the technical and administrative services required to guide and administer the project during construction, but also all the engineering work and blue prints necessary to prepare final construction plans and specifications in order to bid for or contract various jobs or equipment.

3.2.13 Construction expenses

These expenses are necessary for the smooth running of plant construction. They normally include field engineering (inspection, location of equipment, etc.) supplies, construction equipment, and temporary services.

3.2.14 Contractor fees

These vary according to the situation and can be nil when the same firm is in charge of construction and setting-up of the project.

3.2.15 Contingencies

This component covers unforeseen incidents. The amount varies and depends on the precision of the estimate.

3.3 Estimate of Fixed Investment

Estimating the cost of a project can vary from a quick estimate to a carefully prepared detailed calculation using a complete flow chart, with specifications, depending on how much is known about the product and how much time and effort are available for the estimate.

3.3.1 Estimate of the cost of equipment and installations

There is a large amount of literature on the cost of equipment and construction of plants. This literature is valuable for the process engineer, but must be used wisely (as in the majority of cases the data on costs are published without any explanation of from where they were derived). Two factors must be taken into consideration:

- Equipment Cost Indexes - Time

- Cost Factor - Capacity

3.3.1.1 Cost indexes

A problem usually to be faced by whoever does the estimate is that the available information on the cost of similar equipment or plants, is usually out-of-date, and has to be adjusted following changes in economic conditions over time. This updating can be done through the use of the cost indexes.

A cost index is a number showing the ratio between the price of goods at time ‘t’ and the price of the same at time ‘t base’. If a specific date can be given for a past price, present cost can be determined according to the following formula:

$$\text{Current cost} = \text{Original cost x } \frac{\text{Current index}}{\text{Index at time of original cost}} \qquad (3.1)$$

Cost indexes can be used to make a general estimate, but none takes account of all the factors, such as specific technological advances or local conditions. The most common indices allow for a more precise estimate if the period involved is less than 10 years. Many types of indexes are published regularly. Some can be used for the estimation of costs, others are applied specifically to manpower and specific areas such as construction, materials, etc. For instance, in Argentina, the most accessible indexes are those published by:

- INDEC: Instituto Nacional de Estadística y Censos (National Statistics and Census Institute)
  Cost of Construction
  Consumer Price Index
  Non-agricultural Wholesaler Price Index

- Cámara Argentina de la Construcción (Argentine Board of Construction)
- Fundación Atlántica (Atlantic Foundation): Price Indexes of Inputs for the Fisheries Sector
- Redes-Letter (Redes Magazine)

There are also external publications which contain equipment indexes, such as those published periodically in Chemical Engineering for Processing Equipment (Marshall & Stevens Indexes) and materials, now renamed Marshall and Swift Index. A complete description of these indexes can be found in Stevens (1947).

Other indexes are the Engineering-News Record Indexes for construction, the Nelson Index for refinery construction, etc. Similar indexes may be found in most countries. However, one of the current difficulties in developing countries is the scarcity or complete lack of reliable indexes.

Reliable cost indexes give an indication of the degree of development of a country. In most developed countries some indexes are up-dated precisely even daily or at least weekly. However, in others up-dating is done monthly, yearly or not done at all. In extreme situations, usually compounded by lack of statistics (e.g., fish landings), investment, particularly large investment, becomes very cumbersome and risky.

If indexes are not available, it is advisable to take values and indexes from the country where most of the equipment will be imported.

3.3.1.2 Cost-capacity factor

In general, costs do not rise in strict proportion to size. Nevertheless, the costs of a plant or equipment can be estimated when data are available for a similar project, but of different capacity to the one desired, utilizing the following relationship:

$$I_2 = I_1 \times (Q_2 / Q_1)^x \qquad (3.2)$$

where: I_2 = investment desired for capacity Q_2
I_1 = known investment for capacity Q_1

The exponent x in the equation (3.2) is known as the cost-capacity factor (Chilton, 1950). Its average value tends to be 0.6 and for this reason, the relationship is also known as the six-tenths factor rule. However, 0.6 is an average value and its range varies from values lower than 0.2 to more than 1.0.

Tables giving values of this factor, for chemical plants and equipment, can be found in the literature (Happel, 1958; Bauman, 1964). If the total cost is plotted against capacity on a log-log graph, a straight line will be obtained with a slope equal to cost-capacity factor. However, this does not always happen, and curves might be obtained which show the presence of two or more cost-capacity factors, each covering a certain range and providing better results than an overall average factor.

Regarding the fishery industries some values of coefficient x are listed in Table 3.2, and examples of correlations, related to equipment, are shown in Figures 3.1, 3.2 and 3.3, other equipment costs are listed in Appendix C1 (Zugarramurdi, 1981a).

Table 3.2
Cost-capacity Factors for Equipment in Fish Plants

Equipment	Range	Cost-capacity Factor	Basic Size	Basic Cost (Year)
Rapid Evaporating				
Condensers	80 000-320 000	0.57	140 000 kcal/h	US$ 5 000 (1989)
Evaporators	12 000-24 000	0.67	12 000 kcal/h	US$ 3 000 (1989)
Plate Freezers	10-18 t/day	0.31	18 t/day	US$ 28 000 (1989)
Liquid Freezers	2-8 t/h	0.869	8 t/h	US$ 702 600 (1984)
Continuous Spiral Freezer	0.5-1.5 t/h	0.514	1.5 t/h	US$ 272 220 (1984)
Single Belt Continuous Freezer	0.2-0.6 t/h	0.583	0.6 t/h	US$ 130 560 (1984)
Vertical Freezer	5.5-14 t/day	0.13	14 t/day	US$ 23 250 (1984)
Blast Freezers	5-20 t/day	0.31	5 t/day	US$ 10 000 (1989)
Cold Stores (stowage rate: 10 m^3/t)	500-10 000 m^3	0.628	2 000 m^3	US$ 60 000 (1984)
Flake Ice Machines	20-30 t/day	0.38	20 t/day	US$ 18 000 (1989)
Bone Separator				
Baader	1 100-3 500 lb/h	0.65	1 100 lb/h	DM 50 000 (1990)
Bibun	4 000-5 700 lb/h	1	4 000 lb/h	US$ 16 000 (1977)
Paoli	400-2 200 lb/h	0.69	1 100 lb/h	US$ 14 800 (1977)

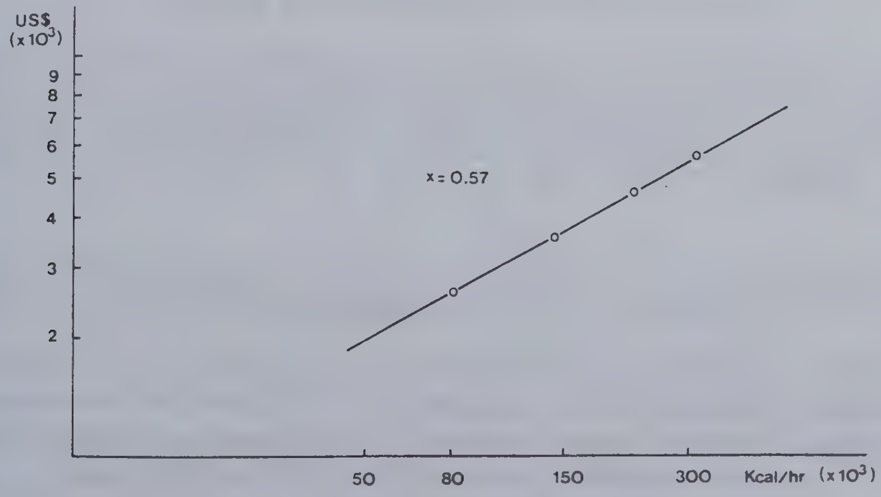


Figure 3.1 Cost vs Capacity for Quick Evaporating Condensers (part of refrigeration equipment)

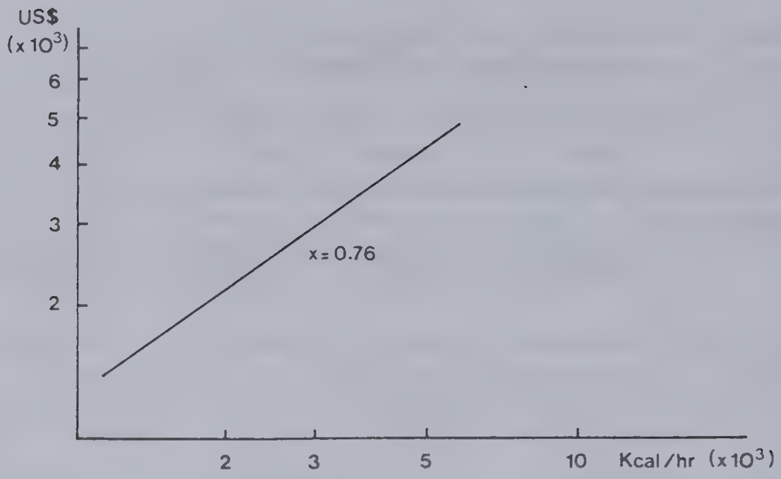


Figure 3.2 Cost vs Capacity for Evaporators (part of refrigeration equipment)

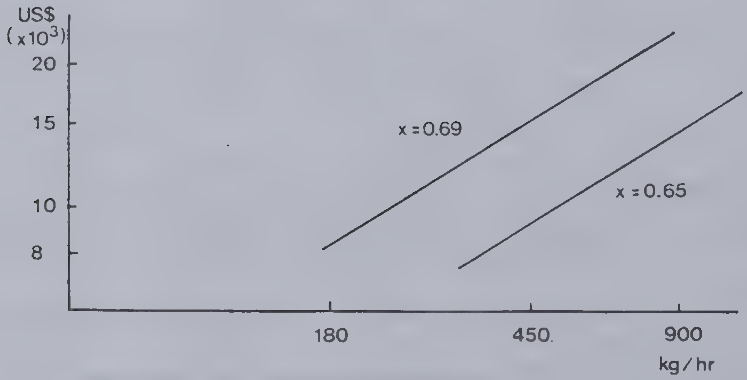


Figure 3.3 Cost vs Capacity for Fish Bone Separator

The value of the cost-capacity factor for refrigeration equipment, in freezing plants with capacities of 10-100 t/day is 0.795, while that for processing equipment is 0.868. In Argentina, the range is very wide, given that when mechanized plants increase capacity, the amount of equipment increases, while the manual plants increase their refrigeration equipment.

Regarding coefficients for whole plants, cost-capacity factors for different types of fish plants, in both developing and developed countries, are given in Table 3.3.

Evidently, there are substantial differences depending on the location of the plant and the processing technology, but it can be concluded that for fish plants (with the exception of fishmeal plants) a 0.85 factor, such as that proposed for solid processing plants, is adequate (Wilson, 1978), while the cost-capacity factor for fishmeal plants is about 0.6.

Table 3.3
Cost-capacity Factors for Fish Plants

Type of plant	Range (t/day)	Capacity Factor	Size (t/day)	Basic Cost (US$ ’000)	Country	Calculated from
Canneries	8-35(°)	0.89	11.3	1 100	Argentina	(Cerbini & Zugarramurdi, 1981a)
Freezing	10-100(°)	0.6-0.81*	20	2 500	"	(Zugarramurdi & Parin, 1988)
Average for other Food Freezing Plants (°)		0.875	20	3 270	Several countries	(Parin *et al*, 1990)
Ice Plants						
Flake	2-200(°)	0.895	50	420	UK	(From Myers, 1984)
Tube	10-200(°)	0.646	50	460	"	"
Plate	2-200(°)	0.960	50	400	"	"
Fishmeal Plants						
	20-100(’)	0.5	66.7	806	Brazil	(From Vaaland & Piyarat, 1982)
		0.459	n/a	n/a	Canada	(From Mensinkai, 1967)
	2-200(’)	0.5	20	400	Tropical Countries	(From Shaw, 1976)
without concentration of stickwater	15-30(’)	0.60	25	235	Europe	(From Atlas, 1975)
with concentration of stickwater	60-250(’)	0.618	60	455	Europe	"
FPC, Biological						
	50-1 000(’)	0.585	50	1 350	USA	(From Almenas, 1972)
FPC, Alcohol extraction**						
	50-1 000(’)	0.502	50	1 570	USA	"
	20-68(’)	0.477	68	1 757	Senegal	(From Vaaland & Piyarat, 1982)

° t product
’ t raw material

* (0-100% according to the degree of mechanization)
** Isopropyl alcohol

3.3.2 Methods of estimating fixed investment

3.3.2.1 Universal factor method

Total fixed capital can be calculated from the current sale price of the product and the annual capacity of the plant (Woods, 1975). Fixed investment is calculated as follows:

$$I = V \times Q / W \tag{3.3}$$

where: I = Investment
V = Sale price per unit produced
Q = Annual capacity of the plant, expressed in the same units of production as V
W = Universal Factor

Table 3.4 shows the values for W. For the application of this method, sale prices and range of capacities in the fishery industry are given in Table 3.5.

Table 3.4
Universal Factor Values

General Application	1.0
Processes where main costs are raw materials or manpower	1.4
Range	0.2 - 8.0

Table 3.5
Average Values of V and Q in the Fishery Industry

Product	Sale Price per unit (V)	Range of Q (1)	Country	References
Fresh sole	US$ 1 928/t	914 t/year	USA	(Georgianna & Hogan, 1986)
Frozen hake (Skinned, boneless fillet block)	US$ 1 470/t	5-20 (t/day)	Argentina	(1990) This work
Frozen sardines	US$ 0.46/kg	30 t/day	Indonesia	(Haywood & Curr, 1987)
Frozen fillet	US$ 2 874/t	3 000 t/year	Senegal	(Jarrold & Everett, 1978)
Argentinean sardines in oil, 170 g can	US$ 0.6-0.7/can	15-100x10^3 cans/day	Argentina	(1989) This work
Canned sardines	US$ 0.46/kg	120 t/day	Indonesia	(Haywood & Curr, 1987)
Canned tuna	US$ 2 704/t	5 500 t/year	Senegal	(Jarrold & Everett, 1978)
Salted anchovy drums x 200 kg	US$ 1.3-2.0/kg	(t/season) 40-4 000	Argentina	(1989) This work
Fishmeal	US$ 0.1/kg	1 200 t fish/year	Indonesia	(Haywood & Curr, 1987)
Fishmeal	US$ 312/t	25 000 t/year	Senegal	(Jarrold & Everett, 1978)

Note: (1) In the same units as V

The value of this method is its simplicity. This advantage is lost if the analyst tries to find in the list of values for W that which corresponds to the particular case in mind. Thus, the term 'Universal Factor' is used since the W factor is supposed to be applicable to any process. In its favour is the little time it takes to make the estimate (5 minutes) but there is a very wide uncertainty range in the result (between -70% and +200%).

3.3.2.2 Lang factor method (f_L)

This technique is frequently used to estimate the order of magnitude of investment. It establishes that the costs of an industrial plant can be obtained by multiplying the costs of the basic equipment by a factor (Jelen and Black, 1983). Two factors are used: one to estimate fixed investment and the other to estimate total investment. Average values of these factors can also be found in the literature. Application is very simple:

Estimated investment = f_L x (Cost of basic equipment)

This method is used when little or no information is available on design. It is a preliminary approximation (±20-30%). The method was first applied in the chemical industry and the general factors for this type of industry are presented in Table 3.6.

Table 3.6
f_L Factors to Estimate I_F and I_T for Chemical Plants (after Arnold and Chilton, 1963)

Type of Plant	f_L for I_F	f_L for I_T
Solid processing	3.9	4.6
Solid-liquid processing	4.1	4.9
Liquid processing	4.8	5.7

For fish processing plants, I_F and I_T factors calculated from published data are given in Table 3.7 for artisanal fish processing and in Table 3.8 for industrial fish processing.

Table 3.7
Average f_L Factor to Estimate I_F for Artisanal Fish Processing

Type of Process	Average Factor
Canning	2.485
Freezing	2.6
Dry and dry salting	2.43
Fishmeal and biological fish silage	2.265

A marked difference is observed in Tables 3.6, 3.7 and 3.8 between the factors used for fish plants and chemical plants. This is probably due to a larger auxiliary infrastructure in chemical plants, not often existing in food factories.

On the other hand, mechanized plants in industrialized countries, with a high proportion of equipment costs, show a factor which is substantially lower for the same type of process. It is also noted that this difference is not compensated for by lower construction costs in developing countries (see Table 3.1).

Table 3.8
f_L Factors to Estimate I_F and I_T for Fish Processing Plants

Type of Plant	Fish Plants		Country	Data calculated
	f_L for I_F	f_L for I_T		
Canning, Manual	2.5	3.1	Argentina	
″	2.47	2.97	Indonesia	(From Haywood & Curr, 1987)
Mechanical	2.05		Norway	(From Myrseth, 1985)
Freezing	2.6	3.3	Argentina	(Parin *et al*, 1990)
Manual	2.29		Tropical Countries	(From Street *et al.*, 1980)
Manual, shrimp	2.93		UK	(From Graham, 1984)
Mechanical, shrimp	2.11		USA	(From Bartholomai, 1987)
Mechanical, catfish	2.31		USA	″
Dry Salting	2.2		Brazil	(From Vaaland & Piyarat, 1982)
	2.67		African Countries	(From Waterman, 1977)
FPC	1.64		Senegal	(From Vaaland & Piyarat, 1982)
	1.59		USA	(From Almenas, 1972)
	2.89		Brazil	(From Vaaland & Piyarat, 1982)

3.3.2.3 Estimation methods by factors

Using this method, it is possible to extrapolate the cost of a complete system from the cost of the main equipment of the process (Chilton, 1949); and to produce an estimate of the total fixed investment within an error of 10-15% of actual value, if appropriate factors are used. It is advisable to adjust the experimental factors pooling results from different and successive cases.

The data for this method can be used in developing cost equations in order to optimize stages of a particular process. The starting point of this method is the estimation of the investment of main equipment of the process, which will be called I_E. It can be observed that the costs of other essential items needed to complete the system can be correlated with investment in main equipment and that total investment can be estimated by applying experimental factors to the basic investment I_E.

The equation (3.4) is thus obtained, in which the experimental factors f, are obtained from a study of various similar processes.

$$I_F = I_E \times (1 + \Sigma f_i) \times (1 + \Sigma f_{Ii}) \qquad (3.4)$$

where:

I_F = Fixed investment for the entire system
I_E = Costs of main equipment once installed
f_i = Multiplication factors for estimation of direct costs, such as piping, instrumentation, buildings, etc.
f_{Ii} = Multiplication factors for estimating indirect costs, such as engineering fees, contractors, contingencies, etc.

Table 3.9 presents typical data compiled from analysis of existing chemical processes (Rudd and Watson, 1968), along with calculated values for fish plants. It is interesting to observe that investment in main equipment can be as low as a half, a third or sometimes a quarter of total investment, depending on the nature of the process.

When the auxiliary services have a general and continuous use in other processes within an industrial complex, an internal price based on the quantities to be consumed is generally charged to the project. When this quantity cannot be accurately measured, a factor is included, usually an annual fee, proportional to I_F. At the other extreme is the case of the plant totally isolated from any industrial complex ("grassroots") which must provide all its auxiliary services and whose investment is included in I_F.

It is emphasized that, due to the enormous costs involved in supplying auxiliary services, linking up with state terminals, loading and unloading terminals, transport and other necessary services in a completely undeveloped site, the total fixed investment necessary for a new plant located in a remote area, can be almost 100% greater than that of a plant built near to an already existing one.

Figure 3.4 shows the relationship between the fixed investment for chemical and petrochemical plants compared with food processing plants (Parin and Zugarramurdi, 1994). Clearly, for a particular capacity of production, there is a difference in the order of magnitude between both types of plants.

Table 3.9
Factors Required to Estimate Total Investment in Fish Plants

Cost of Installed Processing Equipment **Experimental Factors as a percentage of I_E**	$I_E = I_{equipment} \times 1.2$ (*) f_i	**Data calculated from**
1. Piping for the process		
Chemical plants (solid process)	0.07-0.10	(Rudd & Watson, 1968)
Canning, Argentina	0.03	
Freezing, Argentina	0.05	(Parin *et al.*, 1990)
Shrimp, USA	0.056	(Bartholomai, 1987)
Catfish, USA	0.023	"
Salting and Dry-salting, Argentina	0.01	
Fishmeal, Argentina	0.05	
2. Instrumentation		
Chemical plants (little automation)	0.02-0.05	(Rudd & Watson, 1968)
Canning, Argentina	0.01	
Freezing, Argentina	0.03	(Parin *et al.*, 1990)
Salting and Dry-salting, Argentina	0	
Fishmeal, Argentina	0.01	
3. Structures, Buildings		
Chemical Plants (open structure)	0.05-0.2	(Rudd & Watson, 1968)
(half open structure)	0.2-0.6	"
(closed structure)	0.6-1.0	"
Canning, Argentina	0.6	
Norway	0.63	(Myrseth, 1985)
Tuna, Indonesia	0.607	(Bromiley *et al.*, 1973)
Tropical Countries	0.43	(Edwards *et al.*, 1981)
Freezing, Argentina	0.6	(Parin *et al.*, 1990)
Tropical Countries	0.43	(Street *et al.*, 1980)
Shrimp, USA	0.88	(Bartholomai, 1987)
Catfish, USA	0.76	"
UK	0.49	(Graham, 1984)
Salting, Argentina	0.6	
Drying, African Countries	0.71	(Waterman, 1977)
Brazil	0.4	(Vaaland & Piyarat, 1982)
Fishmeal, Argentina	0.5	
FPC, USA	0.1	(Almenas, 1972)
Senegal	0.44	(Vaaland & Piyarat, 1982)
Brazil	0.4	"
Total Physical Cost	$I_E (1 + \Sigma f_i)$	
Average direct cost factors for,		
Canning	1.61	
Salting and Dry-salting	1.57	
Fishmeal	1.51	
Freezing	1.69	

(*) see section 3.2.3

Experimental factors as Percentage of Physical Cost	f_{Ii}	
Engineering and Construction		
Chemical plants	0.2-0.35	
Fish plants, Argentina	0.1	
Tropical Countries	0.1	(Edwards *et al.*, 1981)
Size Factor		
Small commercial unit, chemical plants	0.05-0.15	
Fish plants, canning, Argentina	0.1	
freezing, Argentina	0.1	
Contingencies		
Chemical plants	0.1 - 0.2	
Fish plants, Argentina	0.1	
Tropical countries	0.1	(Edwards *et al.*, 1981)
Indirect Cost Factors	$f_I = (1 + \Sigma f_{Ii})$	
Average indirect cost factor	1.3	
Total Fixed Investment	$I_F = I_E (1 + \Sigma f_i) f_I = I_{equipment} \times f_T$	
Total experimental factors	f_T	
Canning	2.51	
Freezing	2.63	
Salting and Dry-salting	2.45	
Fishmeal	2.36	

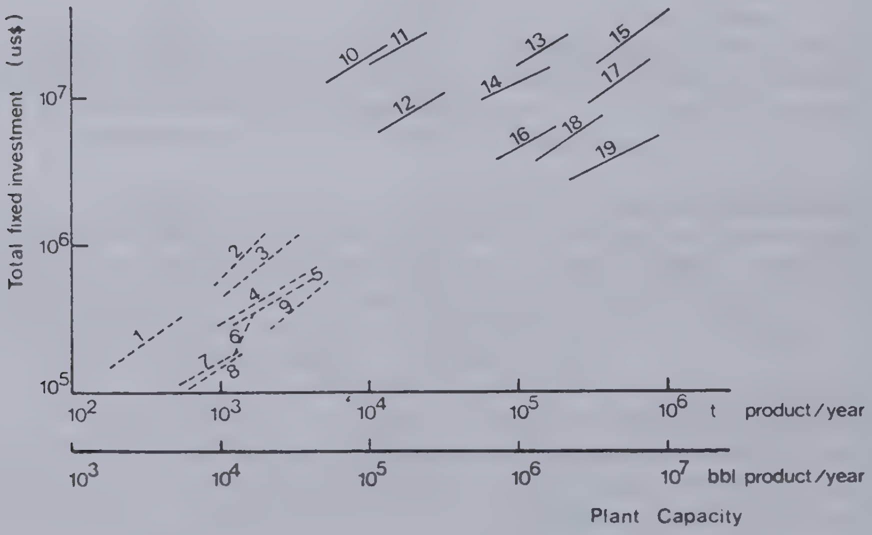


Figure 3.4 Investment for Chemical and Food Plants

Ref.: 1. Sardines, canned (Norway); 2. Lemons, packaging (CA, USA); 3. Sardines, canned (Argentina); 4. Green peas, canned (CA, USA); 5. Lima beans, canned (CA, USA); 6. Pears, production (CA,USA); 7. Green peas, frozen (CA, USA); 8. Lima beans, frozen (CA,USA); 9. Frozen spinach (CA, USA); 10 Polyethylene (USA); 11. Alkylation (USA); 12. Acetic acid (USA); 13. Ammonia (USA); 14.Methanol (USA); 15. Reforming (USA); 16 Nitric acid (USA); 17. Cracking (USA); 18. Ammonium Nitrate (USA); 19. Polymerization (USA).

Note: bbl (US barrel) = 0.119 m³

3.3.3 Level of accuracy in estimation by factors

Errors in these methods are mainly due to: factors of scale, the extension to cases different from those from which the factors used were estimated, and variation of the relationship between equipment and plant costs according to equipment maker and equipment quality. Precautions must be taken with respect to errors introduced in the use of factor methods.

These errors include that of trying to correlate costs using a single independent variable (a correlation error), that of presenting the data by a simple exponential relationship (linear correlation error), that of not considering technological or learning behaviour in the correlations, and that of special circumstances. Each will be analysed separately.

A compromise between simplicity and accuracy is sought. In general, the independent variable which may minimize the error is selected. However, this simplification can introduce significant errors.

In Figure 3.3, cost data for bone separators are presented as the most significant independent variable which, in this case, is processing capacity per hour. The difference between the curves shows the difficulty of presenting costs by a simple correlation and the error involved in such simplification. This difficulty is aggravated when comparing data from various manufacturers and for a greater number than used in the example.

The second type of error is due to the attempt to correlate the data in a simple exponential form, such as in equation (3.3), and in the approximation done by the freezing plants in Figures 3.5 (Zugarramurdi and Parin, 1988) and 3.6 (Cerbini and Zugarramurdi, 1981b).

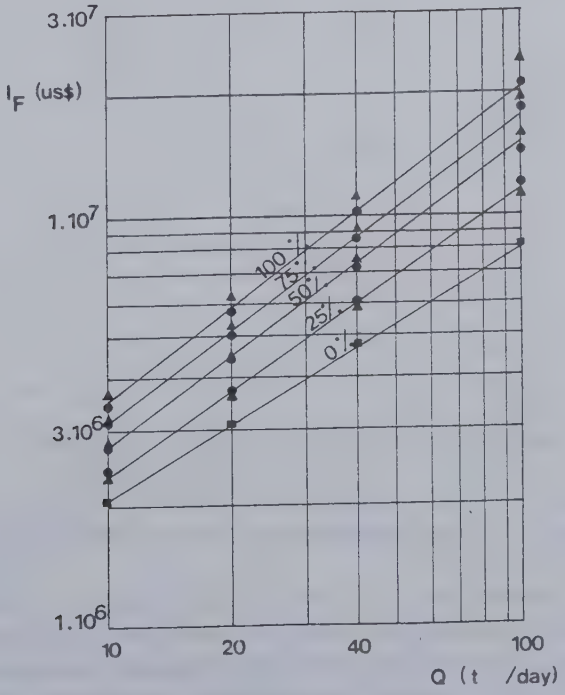


Figure 3.5 Investment vs Plant Capacity for Frozen Fish Plants with Different Levels of Mechanization

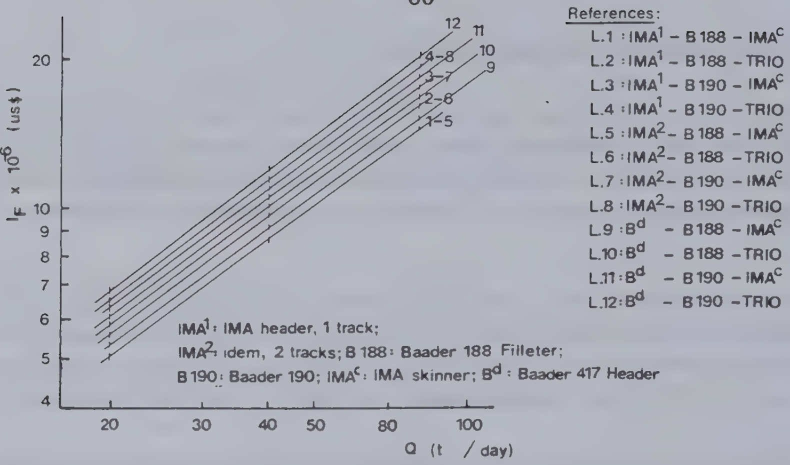


Figure 3.6 Relationship between Investment and Capacity for Mechanical Fish Filleting and Freezing Plants

"Tails" or extremes of production capacity are not usually correlated. They are taken as the maximum and minimum sizes of equipment or plants for usual production techniques. In this case, the "tails" are replaced by size restrictions. An increase in capacity over this maximum is obtained by duplicating the plant or equipment.

For equipment smaller than the minimum size, only the minimum size is obtained subject to appropriate modifications. In Figure 3.7, for canning plants, it is observed that the investment values for the smallest plants deviate from the estimate line, indicating that sizes smaller than the minimum cannot be extrapolated without introducing significant errors (Parin and Zugarramurdi, 1987).

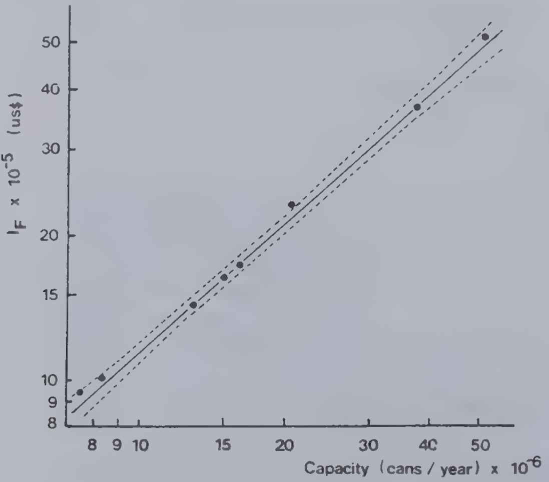


Figure 3.7 Fixed Investment vs Canning Plant Capacity

The third type of error concerns technological advances. When new methods of manufacturing or constructing equipment are developed, the "old" correlations are usually discarded. Given that many correlations are updated by inflation indices, care must be taken that the correlation refers to current manufacturing techniques. The error of special circumstances occurs since correlations can be based on a manufacturer's price list, on a company's actual purchase price, or a mixture of the two.

The actual sale price depends on these factors (on a supply and demand basis), i.e., how anxious the manufacturer is to sell the equipment and the previous business relationship between manufacturer and buyer. In the fishery industry there is also the possibility of purchasing suitable second-hand equipment (adjusted and/or refitted) which allows for a reduced investment; however, estimations in such cases, based on factors presented in Tables 3.7 and 3.9, will yield investment overestimates. The error will depend on the quantity of second-hand equipment utilized. Exchange rates, industry promotion policies and type of technology may also distort the correlations.

Some equipment (e.g., ice plants) may be cheaper if produced in a developing country (e.g., Argentina, Brazil, China, India). This cannot be generalized as the situation will change with time (and the same equipment becomes more expensive). The best advice is to use the methods presented here as starting points and refine the estimate according to local conditions.

3.4 Investment Costs for Fishing Vessels

A fishery is a system composed of different activities such as capture, processing and marketing of fish, which operates within certain socio-economic and political contexts and which interacts with other sectors of the economy. In accordance with the characteristics discussed in the Introduction, two major economic groups are considered: small-scale artisanal fisheries and large-scale industrial fisheries. Table 3.10 gives cost values for fishing vessels in artisanal as well as industrial fisheries. The values in Table 3.10 were plotted on the graph in Figure 3.8, and a cost-capacity factor of 0.65 was obtained for vessels.

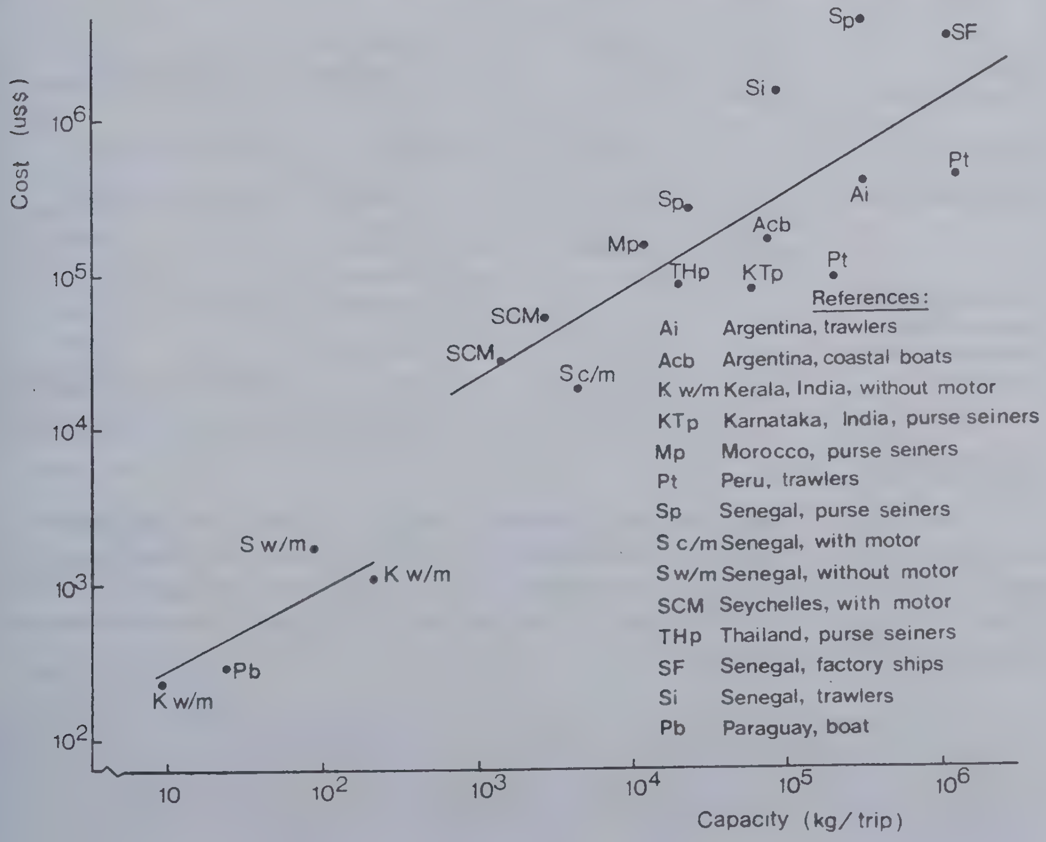


Figure 3.8 Investment Costs for Fishing Vessels

Table 3.10
Investment Costs for Fishing Vessels

Type	Size			Cost (US$ '000)	Country	References
	Length(m)	HP	t			
Coastal boats	18.5-21	380	40	200-250	Argentina	(Parin *et al.*, 1990)
Trawler	33	500	182	500	Argentina	(Otrera *et al.*, 1986)
Canoe (without motor)	10	-	0.075	1.9	Senegal	(Jarrold & Everett, 1978)
Canoe (without motor)	4-5	-	0.020	0.163-0.285	Paraguay	(FAO, 1991)
Canoe (with motor)	14	20	3	19.15	Senegal	(Jarrold & Everett, 1978)
Purse Seiners	20	300	15	355.2	"	"
Trawler	40	1 000	50	2 220	"	"
Factory Ships	50	1 700	540	4 400	"	"
Tuna Purse Seiners	55	1 800	175	6 216	"	"
Catamaran,						
for sardine	3-4	-	0.009	0.230	India	(Kurien & Willmann, 1982)
for shrimp	3-4	-	0.008	0.210	"	"
for anchovy	5-6	-	0.009	0.230	"	"
Canoe	7-15	-	0.173	0.972	India	"
Boats	12	100-125	-	23	Bangladesh	(Eddie & Nathan, 1980)
	12	22	-	5	"	"
Large trawlers	-	-	100-600	120-595	Peru	(Engstrom *et al.*, 1974)
Purse Seiners	13	20	-	35.65	Indonesia	(Haywood & Curr, 1987)
	13.72	102	34.1	108	India	"
	20.5	220	12.6	111	Thailand	"
	22	300	8.1	194.3	Morocco	"
Schooner (standard)	-	37	1.1	33	Seychelles	(Parker, 1989)
Schooner (special)	-	56	2	67	"	"
Schooner (new design)	11.6	70	2	72	Seychelles	"
Boats/RSW*	13.26	15-20	-	76.2	India	(Nordheine & Teutscher, 1980)
	-	35	-	267	India	"

* Refrigerated Sea Water

Small-scale artisanal fisheries generally operates in coastal marine waters in developing countries, the majority of which are located in tropical latitudes (Stevenson *et al.*, 1982). Small-scale fisheries are characterized by a variety of fishing gear and vessels. The fishing techniques are usually labour-intensive and the types of gear used are diverse and relatively economical to operate.

The greatest determining factor for costs is the combination of boat/gear used. The magnitude of the different costs for any of these fishing combinations depends on duration of trip, distance to the fishing area, etc. Small-scale fisheries exploit many species, using a variety of boats, gear and manpower. These different fishing units or types of business have different effects on the resources, just as in their economic operation. The effective effort that each exercises on a particular species is different, as is the average size of fish that each catches.

This analysis does not assume to exhaust the subject of investment on fishing vessels which would merit a separate manual (like aquaculture and mariculture), but merely indicates that the techniques of economic engineering can also be applied to fishing vessels and gears.

The authors are also aware that in practice, within a company, separation of fishing and processing operations may not be as sharp as when the same subjects are analysed from an academic or administrative point of view. Fish technologists must also be aware of this.

3.5 Investment Costs for Fish Containers

Containers are used to handle and transport fish and other fish resources from the time of catch, storage and processing, to their consumption. In many countries, the handling of fish without adequate containers causes deterioration of 20-30% of the fish. Fresh fish loses its quality easily, and thus appropriate containers are needed to prevent contamination, physical damage and spoilage.

There is a great variety of sizes, design and construction of fish containers used throughout the world. Construction materials depend on fishing technique, vessel size, level of organization in the industry, value of catch, and very often, local tradition. Table 3.11 shows data on investment costs for fish containers for both artisanal and industrial fisheries.

Table 3.11
Investment Costs for Fish Containers

Type	Capacity (kg)	Cost (US$)	Useful (years)	Country	References
Basket	25	0.94	1-2	Ghana	(Essuman & West, 1990)
Fresh fish:					
Palm baskets	20-25	0.94	6-12 months	"	"
Receptacles carried on the head					
aluminum	20-25	8.3	5-10	"	"
plastic	20-25	3	3-5	"	"
Dry anchovy:					
Jute bags	45-50	1.9	3-4	"	"
Polypropylene bag	20-25	0.57	3-5	"	"
Wooden boxes	16	4.2	n/a	Norway	(Brox *et al.*, 1984)
	30	5.3	n/a	"	"
Aluminum boxes	12	7	n/a	"	"
	33	25.5	n/a	"	"
Plastic boxes	12	5.5	n/a	"	"
	33	15.2	n/a	Australia	
Insulated containers					
Insulated container (Metal box 70)	70 litre	90	n/a	Denmark	
Metallic container (Artisanal)	144	76	n/a	Paraguay	(FAO, 1991)
Expanded polystyrene container with wood frame and painted (Artisanal)	50 litre	25	n/a	"	"
Expanded polystyrene container	37 litre	14	n/a	"	"

3.6 Investment in Fish Plants

Using the methods described above, it is possible to estimate, with a certain degree of accuracy, the investment necessary for a fish plant, a process line or just a process modification. In fact, the relevant literature contains no detailed calculations, but only descriptions of the main equipment and their costs, construction costs, and data on total investment, from which a global cost for other items can be estimated.

Table 3.12 compiles investment costs for fisheries plants in developing and developed countries. An interpretation of these values will allow conclusions to be drawn.

Table 3.12
Investment Costs for Fish Plants

Type of plant	Capacity (t finished product/day)	Investment (US$ '000)	Country	References
Fresh fish				
sole	3.6	115	USA	(Georgianna & Hogan, 1986)
Canning	11.3 (manual)	1 100	Argentina	(Cerbini & Zugarramurdi, 1981a)
	12	500	Tropical Countries	(Shaw, 1976)
Sardines	1.25	170	"	(Edwards *et al.*, 1981)
Tuna	3	359	Indonesia	(Bromiley *et al.*, 1973)
Shrimp	2.5 (mech.)	810	"	"
Tuna	22	2 088	Senegal	(Jarrold & Everett, 1978)
Sardines	9.75 (mech.)	2 500	Norway	(Myrseth, 1985)
Freezing	20 (manual)	2 500	Argentina	(Zugarramurdi & Parin, 1988)
	20 (mech.)	3 270	"	(Parin *et al.*, 1990)
Filleting and Freezing	12	528	Senegal	(Jarrold & Everett, 1978)
Shrimp	0.9 (manual)	202	UK	(Graham, 1984)
Shrimp	0.9 (manual)	144	Tropical Countries	(Street *et al.*, 1980)
Catfish (live)	13.36	2 400	USA	(Bartholomai, 1987)
Shrimp	2 (mech.)	431	"	"
Ice plants, flake	50	420	UK	(Myers, 1984)
tube	50	460	"	"
plate	50	400	"	"
block	50	800	"	"
	50	791	Senegal	(Jarrold & Everett,1978)
Fish processing	20	175	Tropical Countries	(Shaw, 1976)
Drying	0.2 (mech.)	20	African Countries	(Waterman, 1977)
	0.2 (natural)	6	" "	"
Smoking	0.15	10	Chile	(FAO, 1986a)
Fishmeal (ind.)	16.7	806	Brazil	(Vaaland & Piyarat, 1982)
	5	400	Tropical Countries	(Shaw, 1976)
	12	258	Senegal	(Jarrold & Everett, 1978)
Without concentration stick water	4.5	235	Europe	(Atlas, 1975)
With concentration stick water	34.5	800	Europe	(Atlas, 1975)
Fishmeal (artis.)	0.02	0.111	Tanzania	(Mlay & Mkwizu, 1982)
FPC plants, Biological	6.8	1 350	USA	(Almenas, 1972)
Isopropyl Alcohol	2.8	2 820	USA	"
"	8.5	1 757	Senegal	(Vaaland & Piyarat, 1982)
Aquaculture of shrimp	1 ha	5-10	Tropical countries	(Magnet, 1989)

The values of Table 3.12 are plotted in Figure 3.9. In this graph, it is seen that even when some of the existing plants in developing countries are artisanal, and generally smaller than those in industrialized countries, the relationship between costs and capacities proposed earlier, still applies.

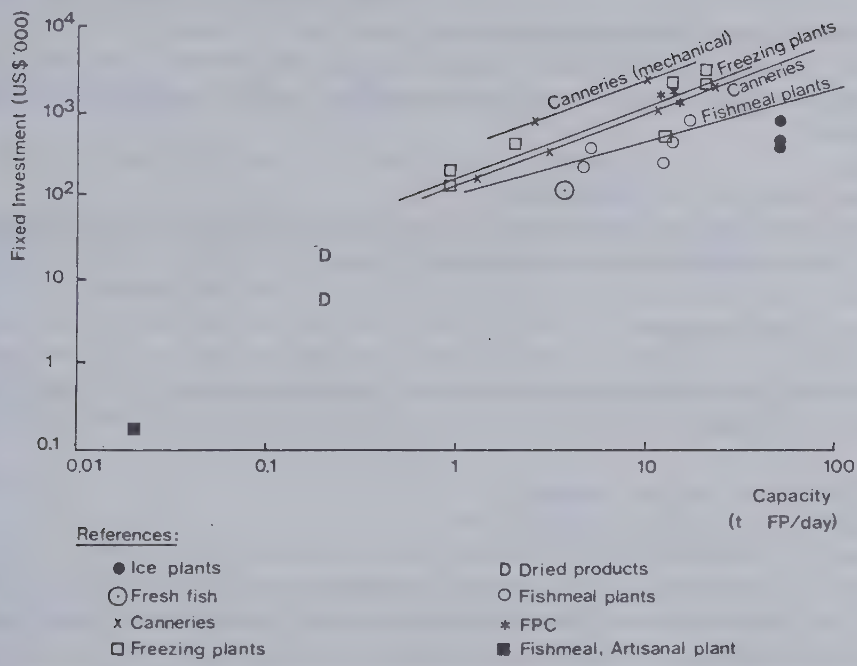


Figure 3.9 Investment Costs of Fish Plants (FP : finished products)

In the case of canning plants, the graphical correlation shows a cost-capacity factor of 0.868 (r = 0.9998), while freezing plants have a factor of 0.825 (r = 0.921). It results that industrial plants of varying sizes operating in different countries (conditions) show a clear correlation between investment and installed capacity, provided the same technology is used. If technology varies, there are two possible situations: when the technology is partly modified (change of one or a few stages of the process); or when the technology used to obtain the same product varies substantially. The former can be seen in Figure 3.5 where data for freezing plants are shown according to mechanical or manual processing. The same data are shown for canning plants in Figure 3.7. The second case is illustrated in Figure 3.9, at point (■), using the production of fishmeal at the industrial and artisanal levels.

In practice, there is a minimum limit for industrial production capacity. This limit is set by the minimum capacity of key equipment on the market. It is obvious from Figure 3.9 that the minimum scale of production requires an investment which also correlates with the maximum scales of production. Besides, these results show that minimum sized plants in developing countries, with partially modified technology, are not comparatively less expensive than large capacity plants in developed countries.

The concept of minimum size can be compared to the results of Figure 3.7 and the experience of pilot plants of institutes, in the sense that investment for minimum size plants or plants below minimum size is even greater than that which would correspond to the correlation shown in Figure 3.9. In general, this is due to the need to incorporate one or more oversized (or exceeding minimum scale) pieces of equipment. All these aspects must also be integrated into costs, as will be examined in Chapters 4 and 5.

3.7 Working Capital (I_w)

Working Capital is mainly made up of:

- Inventory (raw material, semi-finished products, stock of spare-parts, operational materials)
- Cash
- Credit to buyers, outstanding bills
- Credit from suppliers (when considering this section, bear in mind that its value must be deducted form the rest of the Working Capital).

3.7.1 Stock of raw materials

Logically, the quantity of raw materials that must always be kept in stock depends on many factors, but mainly on:

- Its origin, national or imported
- Availability, number of suppliers, etc.

In the case of national raw materials, an average value equivalent to 15-30 days production, at factory price, can be included in the working capital. In the case of imported raw materials, an average of 90-120 days production can be included in the working capital. The value for the raw materials will include costs for importation and transport to the factory. The current tendency is to reduce as much as possible the stock of raw materials, final products, package material, spare-parts, etc., since storage increases costs and immobilizes capital. The management technique used in this case is called "just in time".

3.7.2 Products being manufactured

This component includes the value of raw materials, services, direct manpower needed for factory production. Its magnitude depends basically on the process (continuous or batch).

3.7.3 Semi-finished or test products

These are products which still have to go through other production processes, before being placed on the market, or which are still awaiting laboratory approval. Cost can be high in industries where approval of products takes a long time.

3.7.4 Finished products

Many factors can determine the quantity of a finished product that is kept in storage. Storage of finished products in a freezing factory which only produces fillet blocks will be very different to that of a canning factory which makes a great variety of products. Similarly, there are some products which are consumed in greater quantities during particular periods of the year (for example Easter in Christian countries) while others are consumed regularly throughout the year. In the case of salted fish, the storage of salted products which must pass through a curing process (for example, anchovy), and remain stored for a long period (usually 4-6 months until shipping) are a considerable strain on the working capital, which at times, is of the same importance as fixed investment costs. When not dealing with a specific case and when no other data are available, 30 production days are usually taken as average storage time for finished products. As seen in section 3.7.1 the current tendency in the food and fishery industry is to reduce stocks as much as possible following the policy "just in time". The appropriate application of this policy allows for reduction in the stocks of finished material (immobilized capital), reduction in storage room capacity and hence in investment and operation costs (e.g., electricity).

3.7.5 Stock of spare-parts and operational materials - in stores

The value of the spare-parts can vary within a very high price range, especially if at the start of operations, a plant could have imported equipment from abroad, which is usually provided with spare-parts for several years' operation. From the point of view of the project, the value of the spare-parts is generally estimated as the equivalent of 1 to 3 months operation, bearing in mind the total yearly amount that has been taken to calculate the cost of sales. A similar criterion is followed for operational materials, assigning the equivalent of a month's expenditure to working capital, which will be kept permanently in storage.

3.7.6 Cash

Cash is the amount of money in hand that must be kept available to ensure plant operation, payment for raw materials, salaries, services, etc. Usually the cash for a project is equivalent to 30 days of the total production costs minus depreciation.

3.7.7 Outstanding bills or credit to buyers

This is usually one of the most important components of working capital. Several factors exercise an influence on the calculation of its volume, but the most important is the credit conditions fixed by the market. Each business has its own policy, which can vary from 30 to 60 to 365 days. On the domestic market, it is usual to provide credit to supermarkets for fishery products; for instance, 30 days are given for canned fish in Argentina.

3.7.8 Credit from suppliers

All the previous components constitute gross working capital. It is advisable not to take into account the possible credit that might be obtained from suppliers. However, it should be considered in financial analyses of the project in order to correct the value. In the case of inputs for fish plants in Argentina, this credit is granted by fish suppliers, with a limit of 15 days for national raw material and 30-90 days for imported raw material.

3.8 Estimating Working Capital (I_w)

Various methods can be used to estimate working capital, among which:

(a) Take it as 10-20% of fixed investment. Generally, 10% is used as an acceptable approximate estimate for fish industries when data are lacking.

(b) Take it as 10% of annual sales. Table 3.13 shows average percentages of annual sales for each component, the fraction of the year (decimal) during which working capital is needed, and finally, the average costs of each component as a percentage of the annual sales. It can be observed that the average working capital is approximately 10% of annual sales (Bauman, 1964).

(c) Calculate the inventory costs for one month's capacity of raw material, plus two months' capacity of finished products. Add the accounts receivable calculated on one month's sales (Woods, 1975).

Table 3.13
Calculation of Working Capital

	% Annual Sales	Average Time	Average Costs as % of annual sales
Current Assets			
Raw Material	30	0.04	1.2
Finished Product	60	0.08	4.8
Outstanding Bills	100	0.10	10.0
Cash in Hand	1-5	1.00	2.5

			Total : 18.5
Current Liabilities			
Taxes	8	0.60	4.80
Salaries	14	0.03	0.42
Services	4	0.10	0.40
Freight	2	0.01	0.02
Raw material	30	0.10	3.00

			Total : 8.64
WORKING CAPITAL: ASSETS - LIABILITIES = 9.86			

Example 3.1 Calculation of Total Investment for a Frozen Fish Plant

The purpose of examples 3.1 and 3.2 is to explain and give procedures for the practical calculations of capital investment. The described methods can be applied to such different technologies as freezing, canning and fishmeal plants or to plants singly at an already industrialized site, or to such different sizes as pilot plant and high-capacity units, whenever the reader should follow, understand and use the information properly. The indications of price, both for equipment and for materials, are only estimates, and a supplier whose working conditions are established will be the best source of information on this point. The reader should adapt the approach to the specific problem. Cost data vary with the date, equipment size, plant location, manufacturers' design, materials of construction, the process involved and other factors.

Appendix C1 is intended only as a guide for estimates and represent values for the sizes listed in the year indicated in the source. The six-tenths factor may be employed for general approximations at other capacities, but the user is warned that these may lead to considerable possible error. Experience and judgment can reduce the error, but accurate costs can only be obtained from manufacturers. The methods applied in the examples are not the only ones to be found in the bibliography, and the reader might be interested in looking further into other more accurate and therefore more sophisticated models. Some cases may require more detailed models. In connection with the use of published cost data, it should be emphasized that they are satisfactory only for approximate cost estimations. Where a more accurate figure is desired, it is necessary to obtain quotations from manufacturers for the specific piece of equipment required.

1) Calculate the fixed investment for the frozen hake plant in Example 2.1 by the following methods:
   (a) Lang method
   (b) Multiple-factor method
   (c) Cost-capacity factor for complete plant
2) Estimate working capital
3) Calculate total investment, excluding land

Answers:

1) Table 3.14 shows the main equipment (From Example 2.1) and their delivered costs. The purchased cost of each piece of equipment (quotations from suppliers, 1991) is used to calculate fixed investment (refrigeration system not included at this stage). The term purchased equipment or delivered equipment refers to the cost of the non installed equipment delivered to the construction site. The I_E value can be compared with the estimate made through the correlation proposed by Zugarramurdi and Parin (1988):

Major Equipment Investment in Manual Plants (Without refrigeration system) =
$= \text{US\$ } 59\,485 \times Q^{0.51} = \text{US\$ } 84\,709$

Table 3.14
Cost of Primary Equipment

Equipment Item	Quantity	Delivered Cost (US$)
Whole fish weighing machine		2 000
Whole fish Washer		13 000
Sorting Table (*)	2	400
Filleting Table (*)(**)	16	3 200
Inspection and Trimming Table (*)	5	3 000
Fillet Packing Table (*) (w/conveyor belt)	3	2 700
Fish Block Weighing Table w/scale	1	3 600
Tray remover		1 200
Final Packing Table (*)		3 250
Strapping Machine		5 800
Conveyor Belts		2 500
Tray Washer		14 000
Box Washer		20 000
Plastic boxes, 35 kg fish each	400	4 000
Freezing Trays	200	6 400
Fork-lift truck		6 000
Total delivered cost of major equipment items I_E		91 050

(*) Stainless steel
(**) The number of filleting posts calculated in Example 2.13 is 15. However, filleting tables have an even number of posts, therefore 16 posts instead of 15 is used.

The difference between the two estimates is due to changes in the prices of equipment and inaccuracies since the plant capacity deviates from the valid range (10-100 t of finished product per day).

From the requirements given in Example 2.1., the freezing requirements must be calculated. Table 3.2 gives the data for applying Equation 3.2 to estimate the plate freezer and the cold store.

$$I_{\text{plate freezer}} = \text{US\$ } 28\,000 \times (2/18)^{0.31} = \text{US\$ } 14\,200$$

$$I_{\text{cold store}} = \text{US\$ } 60\,000 \times (60/200)^{0.62} = \text{US\$ } 28\,500$$

$$I_{\text{blast freezer}} = \text{US\$ } 10\,000$$

Appendix C1 provides cost data for a given capacity; when no cost-capacity factor is available, the six-tenth rule can be applied.

$$I_{\text{chill room}} = \text{US\$ } 10\,000 \times (20/10)^{0.6} = \text{US\$ } 15\,200$$

Plate Freezer, 500 kg/load	14 200
Chill Room, 0°C, capacity: 20 t	15 200
Cold Store - 30°C, capacity:60 t	28 500
Blast Freezer, capacity: 5 t	10 000
Refrigeration equipment (compressors, evaporators, etc.) for production of 2 t of frozen fish blocks/day (from supplier)	70 000
	US$ 137 900

Investment in Major Equipment = US$ 91 050 + US$ 137 900 = US$ 228 950

(a) Using the appropriate Lang factor (From Table 3.7),

Fixed Investment = US$ 228 950 x 2.6 = US$ 595 270

(b) With the multiple-factor method, each factor has a range of values and the professional must rely on past experience to decide, in each case, whether to use a high, average, or low figure. Table 3.15 shows this calculation.

Results obtained using this procedure have shown high correlation with fixed-capital investment estimates that have been obtained with more detailed techniques. Properly used, these factoring method can yield quick fixed-capital investment requirements with accuracies sufficient for most economic-evaluation purposes.

(c) According to Table 3.3 and Equation (3.2):

$$I_F = \text{US\$ } 2\,500\,000 \times (2/20)^{0.6} = \text{US\$ } 627\,970$$

This value is relatively larger than the other estimates, because 2 t fall outside the valid capacity range for the cost-capacity factor given in Table 3.3.

It will be considered that fixed investment amounts US$ 600 000, excluding land.

2) $I_w = 10\% \, I_F$ (From Section 3.8 a)

$I_w = 0.1 \times$ US\$ 600 000 = US\$ 60 000

3) $I_T = I_F + I_w$

$I_T = 600\,000 + 60\,000 =$ US\$ 660 000

Table 3.15
Use of Factors from Table 3.9 for Capital Cost Estimation (Frozen Fish)

Item	Multiplying factor	Cost of item (US$)
Delivered equipment cost	1.00	228 950
Installed equipment cost	0.20	45 790
	I_E	274 740
Experimental Factors as a percentage of I_E	f_i	
Process piping	0.05	13 740
Instrumentation	0.03	8 240
Buildings	0.60	164 840
Σf_i	0.68	186 820
Total Physical Cost, $I_E (1 + \Sigma f_i)$,		461 560
Experimental Factors as Percentage of Total Physical Cost	f_{Ii}	
Engineering	0.10	46 160
Size Factor	0.10	46 160
Contingencies	0.10	46 160
Total Indirect Cost, Σf_I	0.30	138 480
Total Fixed Investment, $I_F = I_E (1 + \Sigma f_i)(1 + \Sigma f_I)$		600 040

Example 3.2 Calculation of Total Investment for a Fish Canning Plant

1) Calculate the fixed investment for the canned tuna plant in Example 2.2 using the following methods:

(a) Lang method
(b) Multiple-factor method
(c) Compare with values for canning plants in Table 3.12
(d) By cost-capacity factor in Table 3.3

2) Estimate working capital

3) Calculate total investment

Answers:

1) The first step is to calculate the cost of the primary equipment. Table 3.16 shows the development of the estimate; the main equipment (from Example 2.2) and their delivered costs. The purchased cost of each piece of equipment were estimated from other similar plants in Cape Verde.

Table 3.16
Cost of Primary Equipment

Equipment Item	Quantity	Delivered Cost (US$)
Reception, crane	1	2 000
Weighing, 0.5 t scale	1	1 700
Washing, 2 000 l tank	1	300
Heading and gutting, large table with saw	1	4 500
Washing, tank	1	300
Cutting, large table with saw	1	4 500
Washing, tank	1	300
Placing on trays, large table	1	200
Tray capacity, 40 kg each	20	200
Crane and two tray carriers	1	1 900
Cooking, insulated container	1	1 128
Cleaning of cooked fish, large table for two workers		400
Packaging, large table	1	200
Filling with oil and seal, seamer: 10 cans/min	1	6 900
Sterilization, retort: 700 cans/load	1	16 000
Labelling, large table	1	100
Boiler, 250 kg steam/h	1	8 900
Total delivered cost of major equipment items	$I_{\text{equipment}}$	49 528

(a) Using the appropriate Lang Factor (From Table 3.8)

Fixed Investment = US$ 50 000 x 2.485 = US$ 124 250

(b) Using the multiple-factor method, each factor has a range of values and the professional must rely on past experience to decide, in each case, whether to use a high, average, or low figure. Table 3.17 shows the development of the estimate.

(c) From the data given in Table 3.12, fixed capital investment for a manual canning plant to elaborate 1.25 t finished product/day located in tropical countries, is US$ 170 000. This value is about 30% higher than the total fixed investment calculated previously.

Data from Table 3.12 should be used only in absence of more specific information.

Table 3.17

Use of Factors from Table 3.9 for Capital Cost Estimation (Canned Fish)

Item	Multiplying factor	Cost of item (US$)
Delivered equipment cost	1.00	50 000
Installed equipment cost	0.20	10 000
	I_E	60 000
Experimental Factors as a percentage of I_E	f_i	
Process piping	0.03	1 800
Instrumentation	0.01	600
Buildings (*)	0.60	36 000
Σf_i	0.64	38 400
Total Physical Cost, $I_E (1 + \Sigma f_i)$		98 400
Total Direct Cost		100 000
Experimental Factors as Percentage of Total Physical Cost	f_{Ii}	
Engineering	0.10	10 000
Size Factor	0.10	10 000
Contingencies	0.10	10 000
Total Indirect Cost, Σf_I	0.30	30 000
Total Fixed Investment, $I_F = I_E (1 + \Sigma f_i)(1 + \Sigma f_I)$		130 000

(*) The cost of buildings can also be estimated according to Myrseth (1985), taking into account that: 20 t of raw material require 4 000 m^2 and the construction cost is US$ 200/m^2. In this case, for 1 t of raw material 200 m^2 will be required and the cost will be US$ 40 000. This value is comparable with the US$ 36 000 obtained in Table 3.17. This means that the two total estimates will be US$ 98 400 and US$ 102 400. It will be considered an average of US$ 100 000 for direct costs.

(d) It should be noted that the capacity interval for the application of the cost-capacity factor, is 8-35 t/day. However, this estimate can be used to obtain the order of magnitude of the investment required.

According to Table 3.3 and Equation (3.2):

I_F = US$ 1 100 000 x $(1/11.3)^{0.89}$ = US$ 127 000

It will be considered that fixed investment amounts US$ 130 000, excluding land.

2) $I_w = 10\%\ I_F$ (from Section 3.8 a)

I_w = 0.1 x US$ 130 000 = US$ 13 000

3) $I_T = I_F + I_w$

I_T = 130 000 + 13 000 = US$ 143 000

4. PRODUCTION COSTS

Production costs (also called operating costs) are the expenses necessary to maintain a plant, processing line or equipment in production. In a healthy company the difference between income (from sales and other sources) and production costs indicates the gross profit.

This means that the economic fate of a company is linked to: the income (e.g., goods sold on the market and price obtained) and the production costs of the goods sold. Whereas income, particularly income from sales, is linked to the marketing sector of a company, production costs are closely related to the technical sector; it is thus essential that the fish technologist knows the production costs.

Production costs have two opposite characteristics sometimes not well understood in developing countries. The first is that to produce goods one must expend; this means produce at a cost. The second characteristic is that costs should be kept as low as possible and eliminated when unnecessary. This does not mean cutting or eliminating costs indiscriminately.

For instance, there is no sense in not having a proper equipment maintenance programme merely to avoid maintenance costs. It would be more advisable to have an acceptable maintenance scheme which would, perhaps, eliminate 80-90% of breakdown risks. Likewise, purchasing fish of marginal quality to reduce raw material costs is not usually recommendable. The right approach would be to have a proper fish purchasing scheme in accordance with the market requirements and costs. Usually neither low nor top quality fish produce an optimum income to the company; this will be discussed later.

Many other aspects understood as "costs" to be eliminated (e.g., plant safety programmes, personnel training, research and development) are often non-existent in the fish processing industry of many developing countries. Unfortunately, in the same way, environmental costs (e.g., treatment of effluents) are very often ignored and, therefore, transferred to the community at large or to future generations.

Another aspect should be examined when analysing the importance given to production costs in developing countries: for a given cost structure, a variation in the sale price will have an immediate impact on the gross profit because the gross profit is the balance between income (mainly from sales) and production costs. Therefore, sale price increases or variations are very often perceived as the most important variable (together with the raw material cost) particularly when considerable price variations exist.

An example of this variation in sale prices is given in Figure 4.1. In this case, the sale prices for canned tuna in brine (48 x 6 1/2 oz) imported into the USA and Europe from Thailand during 1993, show variations of up to 25.75 and 28.58% respectively.

In a situation as described in Figure 4.1, the manager or plant owner could be tempted to disregard the possibility of analysing the whole cost scheme as a way of improving earnings (perhaps with the exception of raw material as will be seen later). The manager will tend to reason that market price variations are of such magnitude as to overshadow any relatively small improvement in the cost structure (e.g., improvements in energy efficiency or in yield). Company efforts are usually channelled only to improve the market position (to sell or to buy) and eventually to obtain global political cost reductions (e.g., tax reductions or exemptions, electricity and petrol rebates, soft loans).

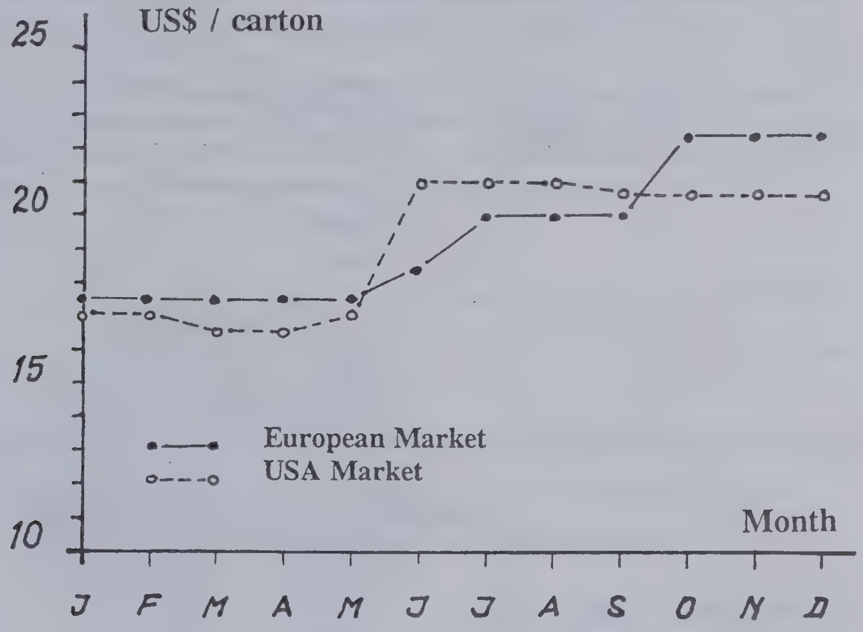


Figure 4.1 Monthly Price of Canned Tuna in Brine (48 x 6 1/2 oz) Imported into USA and Europe from Thailand during 1993 (from FAO GLOBEFISH data bank)

Managers can easily fail to recognize that any improvement in the production costs structure and not only in sale price or raw material cost, will increase gross profit in any market price situation and that this improvement will be cumulative in time. Moreover, this might distract them from technological developments which, in the medium and long term, could make the industry first non-competitive and then obsolete.

Appropriate concern for the rational management of all production costs is an indication of a mature and developed fishery industry in a competitive international market.

The lack of understanding of the importance of production costs factors, and in particular depreciation, insurance and reserves, make fishery businesses very unstable in many developing countries and often prevents development and self-sustainability, despite the existing opportunities on both domestic and international markets.

4.1 Cash Flow and Production Costs

Cash flow is the clue to costs and profitability studies. Cash flow analysis is useful for understanding movements and timing of cash not only for a complete company but also for partial production lines.

Figure 4.2 shows a general scheme of the cash flow which defines an operation (plant, processing line, equipment) and how it is paid. Production costs can be divided into two large categories: VARIABLE or DIRECT COSTS, which are proportional to production, and FIXED COSTS, which are independent of production. Table 4.1 shows a classification of production costs that can be used as a guide for calculations.

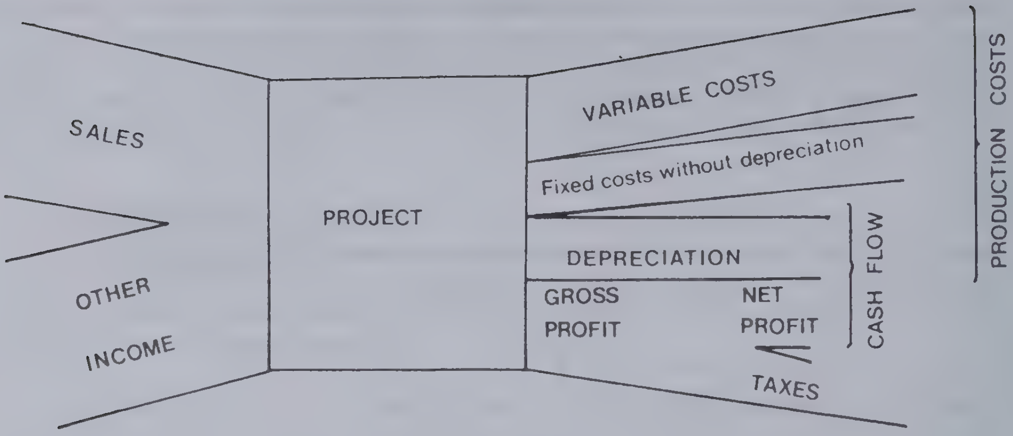

SALES
OTHER
INCOME
PROJECT
VARIABLE COSTS
Fixed costs without depreciation
DEPRECIATION
GROSS
PROFIT
NET
PROFIT
TAXES
CASH FLOW
PRODUCTION COSTS

Figure 4.2 Scheme of Cash Flow for a Fish Processing Plant/Line/Equipment

Table 4.1
Classification of Production Costs

1. VARIABLE COSTS (direct)
    - 1.1 Raw Material
    - 1.2 Direct Labour
    - 1.3 Supervision
    - 1.4 Maintenance
    - 1.5 Utilities
    - 1.6 Supplies
    - 1.7 Royalties and Patents
    - 1.8 Packaging

2. FIXED COSTS
    - 2.1 Indirect costs
        - 2.1.1 Investment Costs
            - 2.1.1.1 Depreciation
            - 2.1.1.2 Property Taxes
            - 2.1.1.3 Insurance
            - 2.1.1.4 Credit (Financing)
            - 2.1.1.5 Other Obligations
        - 2.1.2 General Expenses
            - 2.1.2.1 Research and Development
            - 2.1.2.2 Public Relations
            - 2.1.2.3 Accounting and Auditing
            - 2.1.2.4 Legal Advice and Patents
    - 2.2 Administration and management costs
    - 2.3 Sale and distribution costs

Figure 4.2 shows two main flows: the first is income from sales and services and any other source of income connected to the firm; the second includes expenses and all fixed and variable costs. Gross profit is the difference between the income and expenditure. The relative importance of the flows depends on the type of operation analysed.

For example, capture costs in artisanal fisheries are low, since fixed costs are lowered by small capital invested and variable costs can be reduced by an appropriate combination of vessel and fishing gear used. Production costs for some of these combinations are related to the duration of the fishing trip, distance to fishing area, etc. (Stevenson, 1982).

Industrial production of fishery products is usually intensive in variable costs such as raw materials, labour and packaging. These three components could make up about 80% of total production costs. For example, Figure 4.3 shows a proximal distribution of the costs of producing canned fish in Argentina (Parin and Zugarramurdi, 1987).

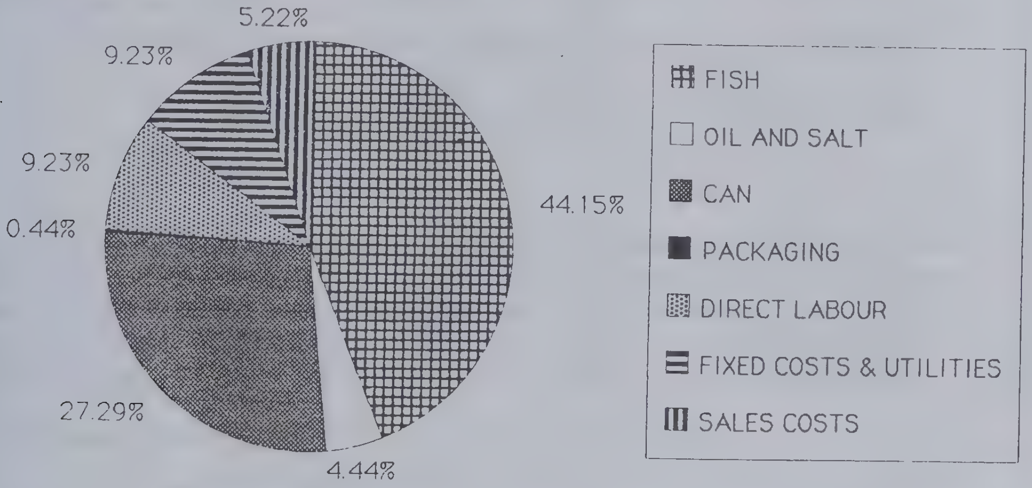


Figure 4.3 Proximal Distribution of the Production Costs of Canned Fish (Argentina)

In Table 4.2 some production costs per 1 kg of finished products for various types of fishery products are listed. The data appearing in Table 4.2 are only indicative and refer to the place and year where they were collected. It should be taken into account that costs per unit depend on installed capacity and production level (see Chapter 3).

Actual production costs are very difficult to find in literature because they are a direct indication of market possibilities. For instance, from Table 4.2 it is clear that production costs of Argentine canned sardines were not competitive on the regional and international market and that eventually even imported canned tuna and bonito could compete with them on the domestic market (something that actually happened when the market was opened). On the other hand, production costs of frozen hake fillet blocks in Argentina and Uruguay make them competitive on international markets at about the same time. With reference to capture costs, values vary widely, depending on the country and type of vessels; examples are shown in Table 4.2.

It is necessary to highlight the difference between accounting for costs, and estimates made in the preparation of a future project. In the first case, a historical fact is analysed, which can be classified and arranged according to the pre-established accounting policies used by the company, and which would have been used to calculate the production cost of a product made in the past. In the second of concern here, estimates are made by trying to calculate the future cost of a product, the production of which could begin soon or one or two years after it has been created.

Table 4.2
Production Costs in Fish Plants

Type of Product	US$/kg finished product	Country	References
Canned			
Tuna, 452 g	1.14	Indonesia	(Bromiley *et al.*, 1973)
Shrimp, 135 g	2.70	"	"
Sardines, 125 g	1.30	Norway	(Myrseth, 1985)
Sardines, 125 g	1.27	Tropical Countries	(Edwards *et al*, 1981)
Sardines, 170 g	2.94	Argentina	(Parin & Zugarramurdi, 1987)
Mackerel, 380 g	1.92	"	"
Hake, 380 g	1.31	"	"
Sardines in sauce, 452 g	0.67	Chile	(1989)
Tuna chunks, 185 g	1.82	Thailand	(1989)
Brine bonito, 185 g	1.64	"	(1989)
Frozen			
Hake fillet block	1.20	Argentina	(1989)
Hake fillet block	1.17	Uruguay	(Kelsen *et al.*, 1981)
White croaker H&G	0.90	"	"
Striped weakfish, IQF	1.17	"	"
Shrimp	2.8	UK	(Graham, 1984)
Shrimp	2.39	USA	(Bartholomai, 1987)
Cod, fillet block	2.88	Canada	(1989)
Alaska pollack, fillet	1.52	Japan	(1989)
Krill, tails, block	3.55	Poland	(Budzinski, 1985)
Fresh			
Sole	4.18	USA	(Georgianna & Hogan, 1986)
Dried			
Naturally	0.28	African countries	(Waterman, 1977)
Mechanically	0.41	" "	"
Fishmeal			
	0.12	Argentina	(Cabrejos & Malaret, 1969)
	0.14	USA	(Almenas, 1972)
	0.15	Peru	(1989)
	0.2-0.33	European countries	(Atlas, 1975)
	0.28	African countries	(Mlay & Mkwizu, 1982)
FPC	0.33	USA	(Almenas, 1972)
Capture			
Purse seiners	0.241	Thailand	(Haywood & Curr, 1987)
Purse seiners	0.021	Morocco	"
Boats	0.038	Bangladesh	(Eddie & Natham, 1980)
Boats	0.435	Seychelles	(Parker, 1989)
Artisanal	0.035	India	(Kurien & Willmann, 1982)
Trawler	0.331	"	"
Gillnet	0.200	"	"
Purse seiners	0.500	Argentina	(1990)
Trawlers	0.300	"	(1990)

An estimate of production costs could be made for several reasons. First, the estimate allows the selection of an operation that will save time, effort and money on non-profitable projects, choosing the most advantageous alternative. Second, the estimate must identify the costs which most influence profitability, so that those components can be specifically determined in future calculations, leaving the other components to more rapid estimates. Estimates of the probable future costs of production are needed to determine financial and economic studies, and could help to take decisions regarding:

- Probable changes in sale prices
- Changes in market situation and changes in the composition of supply

4.2 Variable or Direct Costs

4.2.1 Raw material

This component comprises primary and secondary raw materials directly or indirectly involved in the transformation process (fish, oil, salt, ingredients, etc.), since the primary characteristic of this activity is manufacturing. It can be estimated by knowing:

- Quantity of raw material needed to make one unit of the product
- Price per unit of raw material.

In the fishery industry, there are normally three ways of purchasing fish:

- It can be bought directly at the landing site or fish auction market
- It can be captured by boats belonging to the company
- It can be imported.

In the case of A, raw material costs can be calculated according to the agreed fixed price for seasonal species, or an average price paid according to the current rate for the particular species. For B, raw material costs are taken as the annual costs of operation of the vessels. For example, in Figure 4.4, the capture cost for anchovy by coastal boats in Mar del Plata (Argentina) are shown as a function of the use of the hold (Parin *et al.*, 1987b).

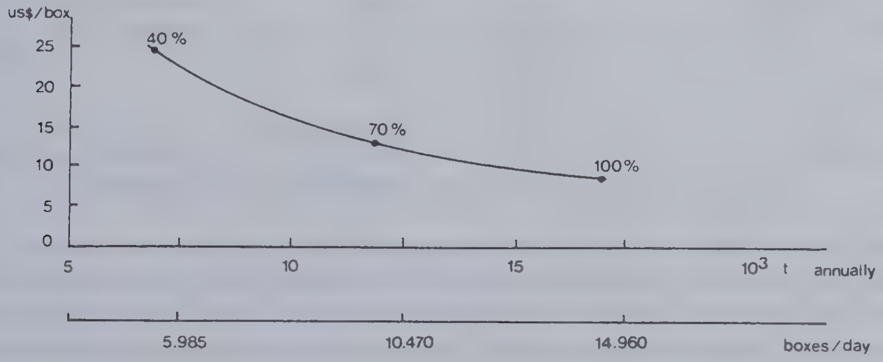


Figure 4.4 Average Capture Costs of Anchovy in Relation to Percentage Use of Fleet

In case C, which involves imported raw materials, cost includes delivery to the plant and other charges as detailed in Table 4.3.

Table 4.3
Constituent Elements of Price of Imported Raw Material

(a) Price at Loading Dock (FOB)	.....
(b) Loading-Destination port transport charges	.....
(c) Marine Insurance	.....
Destination port CIF cost	.....
(d) Customs fees	.....
(e) Other expenses (office, dispatcher, freight)	.....
Arrival at Factory Price	.....

In chemical plants, the raw material component can vary between 10% and 50% of the total production cost. Values given in Table 4.4 can be used as a guide for fish plants.

Table 4.4
Typical Costs of Raw Material as a Percentage of the Total Cost of Production

Type of Plant	% of Total Costs of Production	Country	Data calculated from
Freezing			
Hake fillet	60-70	Argentina	(Parin *et al.*, 1990)
Kingklip	75-85	"	"
Shrimp	54.2-77.1	UK	(Graham, 1984)
Hake	53.8	"	"
White croaker, H&G	48.9	Uruguay	(Kelsen, 1981)
Striped weakfish (with skin IQF)	49.6	"	"
Raw shrimp (headless)	63	USA	(Bartholomai, 1987)
Farmed catfish	91	"	"
Canning			
Sardines, mackerel	23-44	Argentina	(Zugarramurdi, 1981b)
Shrimp	55	Indonesia	(Bromiley *et al.*, 1973)
Sardines	18.5	Norway	(Myrseth, 1985)
Sardines	21.5	Tropical countries	(Edwards *et al.*, 1981)
Fresh Sole Processing Plant	80.4	USA	(Georgianna & Hogan, 1986)
Salted anchovy	50-60	Argentina	(Zugarramurdi, 1981a)
Fishmeal	65	"	(Cabrejos & Malaret, 1969)
"	65.3	Brazil	(Vaaland & Piyarat, 1982)
FPC, type A	35.6	USA	(Almenas, 1972)
"	45.9	Brazil	(Vaaland & Piyarat, 1982)
FPC, type B	47.5	"	"
Drying (natural)	28.6	"	"
"	70	African countries	(Waterman, 1977)
Drying (mechanical)	29.1	Brazil	(Vaaland & Piyarat, 1982)
"	48	African countries	(Waterman, 1977)

Table 4.4 shows that there are substantial differences between processing plants depending on the country to which they belong. Considerable differences exist between dry fish processing plants in Africa or Brazil. It can be inferred that this situation occurs as a result of different salaries paid to workers. The ratio between cost of labour and cost of raw material is 1.5 in Brazil, while this quotient is 0.007 in Africa, despite the fact that the price for raw material is 33% higher in Brazil. Appendix C2 includes additional indicative costs of different species of fish and shellfish. The following expenses may have to be added to these costs:

- Fish Market Charges, or for the place where fish is sold wholesale
- Transport from landing place to factory.

In Appendix C2 raw material costs are shown: the prices of raw material given in Appendix C2 are only indicative, perhaps to be used in a first approximation. However, average and price series should be utilized for appropriate calculations, particularly in cases where the raw material is decisive in the production cost structure (see Table 4.4). The main reason is that raw material costs, in particular fish, may vary widely throughout the year in an open market economy.

Figure 4.5 gives an example of the price of frozen skipjack tuna, raw material for the canning industry of Thailand, for the years 1990 and 1993. From Figure 4.5 it is clear that monthly prices varied during 1993 up to 66%; average prices for 1990 and 1993 were similar. Average prices for 1991 and 1992 were 835.8 and 708.1 respectively which means that, in the long run, variations in average prices are much less marked than monthly variations. In this particular case, not considering 1992 which was a particular year for skipjack tuna, maximum deviations of yearly average prices on the overall average price for 1990, 1991 and 1993 was 1.6%.

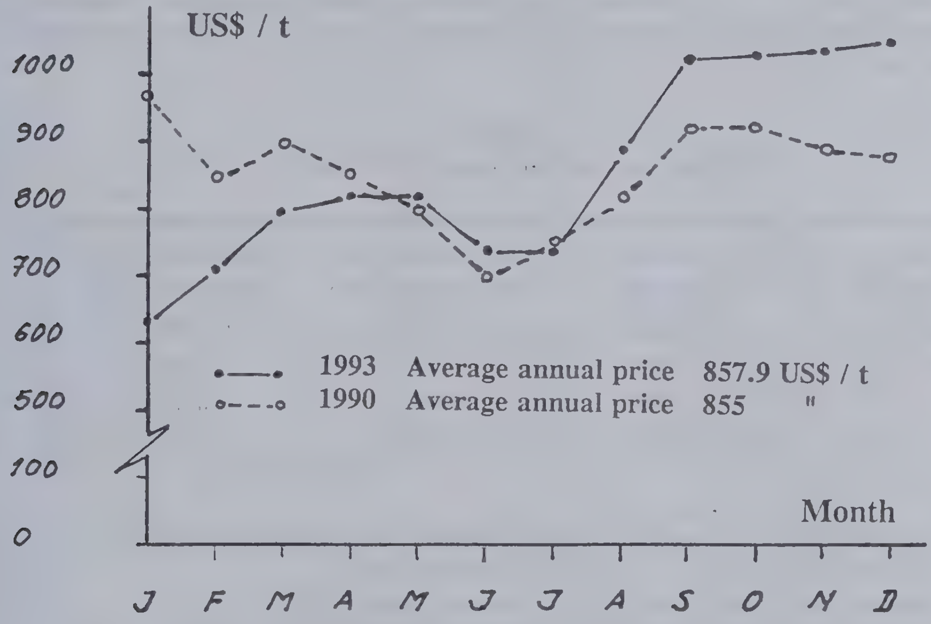


Figure 4.5 Monthly Cost (C & F) of Frozen Skipjack Tuna (4-7.5 lb) in Thailand (years 1990 and 1993) in US$ per ton (from FAO GLOBEFISH data)

Therefore, an analysis of the average monthly and in some cases seasonal variations of raw material costs is normally necessary in the fishery industry. However, as in the case of the sale price, short term wide variations in raw material prices should not make the manager, and in particular the fish technologist, disregard analysis of other production costs.

Example 4.1 The Cost of Salt in Fish Salting in Trinidad

Salt is a raw material to produce salted fish. An incorrect practice in fish salting in developing countries is the large amount of salt utilized (it is not unusual to find ratios of 1:1 and 2:1 of salt to fish). This is probably due to old methods imported from developed countries, where salt was very cheap compared with the price of fish. This is not necessarily always so in developing countries. The authors have recorded prices up to US$ 1/kg of salt paid by artisanal fishermen in developing countries.

Further amounts of salt to those shown in Table 2.6 will not add to the safety of the product, will increase the costs of salt, the cost of handling and processing and the storage costs of salt and salted fish (containers, premises, etc.). Moreover, excessive use of salt fosters the bad practice of salt or saturated brine reutilization observed in many places.

An example from a shark salting plant in Trinidad illustrates this point very clearly. The percentage of salt (approximate plant capacity 1 t raw material/day) was 100% (1:1) for a wet salting method utilizing pressure (salted shark is dried afterwards), and there was no change of brine during salting. Due to problems with the quality of the salt produced locally, imported salt was utilized (a very common situation in many developing countries).

According to the examples discussed earlier (see Table 2.6) 30-40% salt will suffice. A figure of 45% could be adopted to take into account losses (salt lost before it reaches the fish). The use of the 1:1 ratio in this case is excessive. However, even higher rates are utilized in practice in the Caribbean region. For comparison purposes, a 2:1 ratio was also utilized in the calculations and the alternative to salting croaker is also included. The results can be seen in Table 4.5.

Table 4.5
Influence of Salt/Fish Ratio on Production Costs

Ratio Salt : Fish (w/w)	Cost of imported salt per year (1) (2) (4)	Production cost per kg of salted shark (3)	Production cost per kg of salted croaker (3)
0.45 : 1	27 945	3.43	2.82
1 : 1	62 100	3.56	3.15
2 : 1	124 200	3.79	3.63

Notes:

(1) 270 working days per year, plant capacity 1 t/day (material for salting)
(2) Exchange rate US$ 1 = 4.25 TT$ (October 1991)
(3) Round shark price: US$ 0.37/kg; croaker price: US$ 0.37/kg
(4) Salt price: local US$ 0.094/kg; imported (Canada) US$ 0.23/kg

From Table 4.5, it is apparent that the costs of salt will affect the final cost of production significatively, and the incidence is higher in croaker than in shark (the calculation is influenced by the fish cost). Table 4.5 also shows the amount of total reduction in the cost of salt. When unitary prices are calculated there is a tendency to overlook how much it could mean in absolute terms throughout the year. The reduction in production costs and savings could be higher utilizing salt produced locally, even allowing an additional 20% of salt that will be lost during washing to improve quality. The situation should usually be analysed.

The general relationships "cheaper than" or "more expensive than" of developed countries may not apply in all the situations in developing countries. This example also illustrates the need for a management that comprises appropriate technical knowledge at production level.

4.2.2 Direct labour

This includes salaries of workers/employees whose labour is directly identified with production operations. In highly mechanized processes (for instance fishmeal and fish oil plants), this component represents less than 10% of production costs. In operations where much handling is involved, however, it can exceed 25% of production costs. In Table 4.6, average percentages are given for fish plants (Zugarramurdi, 1981b).

Table 4.6

Costs of Direct Labour as a Percentage of the Total Costs of Production

Type of Plant	% of Total Costs of Production	Country	Data calculated from
Canning			
(*)	11-17	Argentina	(Zugarramurdi, 1981a)
Shrimp	9.7	Indonesia	(Bromiley *et al.*, 1973)
Tuna	7.2	"	"
Sardines	9.2	Norway	(Myrseth, 1985)
Sardines	10.5	Tropical countries	(Edwards *et al.*, 1981)
Fresh Sole	12.1	USA	(Georgianna & Hogan, 1986)
Freezing			
Hake fillet (manual)	10-12	Argentina	(Parin *et al.*, 1990)
Hake fillet (mechanical)	7-9	"	"
Kingklip fillet, (manual)	7-9	"	"
Hake (fillet block)	11.1	Uruguay	(Kelsen *et al.*, 1981)
White croaker, H&G	6.7	"	"
Striped weakfish (with skin IQF)	6.0	"	"
Shrimp (manual)	9.3-18.6	USA	(Graham, 1984)
Shrimp (mechanical)	5.35	"	(Bartholomai, 1987)
Catfish (mechanical)	1.8	"	"
Salting of anchovy	9 - 12	Argentina	(Zugarramurdi, 1981b)
Drying (natural)	5.1	African countries	(Waterman, 1977)
" "	42.7	Brazil	(Vaaland & Piyarat, 1982)
Drying (mechanical)	1.7	African countries	(Waterman, 1977)
" "	20.7	Brazil	(Vaaland & Piyarat, 1982)
Fishmeal	6	Argentina	(Cabrejos & Malaret, 1969)
FPC, type A	6.3	USA	(Almenas, 1972)
FPC, type A	5.9	Brazil	(Vaaland & Piyarat, 1982)
FPC, type B	1.4	"	"

(*) depends on the type of production (sardine, tuna)

The two variables which govern this component are the cost of man-hour or man-year and number of man-hours or number of men/women required. To the basic costs of the man-hour calculated according to standard labour agreements, must be added the social charges which are normally the responsibility of the employer. In the case of the Argentinean fishing industry, social charges amounted to 75% (1994) of gross salaries (without allowance for equipment) and include weekends, paid holidays, absenteeism, illness and accidents, social work, social security and bonuses. Elsewhere, this percentage is considerably lower (approximately 21-45%) although it generally does not include as many components.

Unfortunately, from the development point of view, in some developing countries there is no provision for the industry to pay (in practice) social charges. Although it may appear advantageous for the industry, cheap manpower does not automatically mean competitive advantage. Current world tendency is towards a reduction in social charges (both on the part of the worker and the industry) as a means of increasing workers' take-home pay and reducing labour costs at the same time. Appendix C3, gives examples of basic salaries for fishery industry personnel.

In artisanal fishing, the "share system" is very often used to calculate wages for the crew. In some cases once the price of the fish is known or agreed and the general expenses are deducted, the net income from sales is divided into shares. The total number of shares is determined by the number of crew, and the number of shares assigned to the boat and the net. The amount assigned to the boat and net is intended for loan amortization. This figure is partially determined by the costs and useful life of the boat and the fishing gear. To the "shares" for the boat and net is added one part per crew member. In smaller boats, the 'chief' fisherman is often also the owner and his share is equal to that of the other fishermen. In medium sized boats, there is usually an owner and a master fisherman and the former generally gives half a share more to the latter.

The share ratios between boatowner and crew differ slightly from country to country, but the same basic concepts apply. In the Philippines, when the boatowner is also a crew member, the earnings are shared (once expenses have been deducted) by a ratio of 67-33%; with 67% of the net earnings going to the owner of the vessel (owner-fisherman), and 33% being divided up among the crew. When the owner does not work on the boat he receives one-third of the earnings, one-third goes to the master fisherman, and the remaining one-third is divided among the crew (Guerrero, 1989).

In the Seychelles, one-third of the net earnings goes to the vessel owner and the remaining two-thirds to the crew, which includes the owner-fisherman. Thus, the owner benefits from two sources: his share as a crew member and that received as vessel owner, after maintenance repair costs and amortization payments have been made (Parker, 1989).

In Kerala (India), the owner usually participates in the artisanal fishing activity, and gives 32-75% of net earnings to the crew, while in the mechanized sector, where the cost of fuel is a major expenditure, crew wages represent a lower percentage of net earnings: 13% for trawlers and 26% for boats using gillnets. Nevertheless, the average income for a crew member is greater in this case (Kurien and Willmann, 1982). In large-scale fisheries, the crew receives a fixed wage; examples are given in Appendix C3.

4.2.3 Supervision

Supervision consists of the salaries paid to personnel directly responsible for supervising different operations. It represents approximately 10% of the direct labour in the fishery industry. Very often, supervisory personnel (foremen) receive a monthly salary, which means that this component would become a fixed cost of up to 100% of the capacity installed. Also, in this case, social charges must be included in the basic salary. Other percentages used for supervision in the cases examined in the literature are shown in Table 4.7.

Table 4.7
Costs of Supervision as a Percentage of Direct Labour

Type of Product	%	Country	Data calculated from
Canned			
Sardine, mackerel	10.0	Argentina	(Zugarramurdi, 1981b)
Shrimp	12.9	Indonesia	(Bromiley *et al.*,1973)
Sardines	3.5	Tropical Countries	(Edwards *et al.*, 1981)
Catfish	7.1	USA	(Bartholomai, 1987)
Frozen			
Hake	10.0	Argentina	(Zugarramurdi, 1981b)
Shrimp	16.2	UK	(Graham, 1984)
Shrimp, whitefish	16.3	Tropical Countries	(Street *et al.*, 1986)

4.2.4 Utilities

4.2.4.1 Electricity

Once electricity consumption has been estimated in kWh, according to the degree of production chosen, only the cost of the electricity remains to be established. Electricity can be acquired in two different ways, namely:

Purchasing: This is simplest from an estimation point of view, since the electricity supplier will have a fixed price for the kWh entering the factory, according to zone, level of consumption, etc. In Appendix C4, basic rates are given for the cost of electricity supply according to the type of process involved.

Self-generated electricity: This is the case in plants which require large inputs of electric energy. It is also used in fish plants located in zones where self-generating electricity is necessary.

In cases where energy is self-generated, the costs of kWh depend on the factory's production level, i.e., it must be estimated for each possible level of production.

4.2.4.2 Steam

Specific consumption and costs of unit under consideration are the two values required here. Regarding costs of steam, there are several possible sources of steam in a plant:

- It can be produced in boilers, specifically employed for that purpose
- Steam escaping from a turbo-generator for electricity can also be used
- It can be bought from external sources.

The fishery industry usually adopts the first method. In this case, the cost of 1 t of steam is calculated according to the price of fuel, once all other costs have been considered in their particular components. In Appendix C4, international costs are given for fuel.

4.2.4.3 Water

The cost of water depends on many factors. A company may have to purchase water, may produce their own water (from wells, or treating river or lake water) and eventually, as discussed in Chapter 3, could utilize clean seawater for some purposes. Often, companies use a mixture of these features. At the same time, water may be abundant and hence cheap, or scarce and therefore relatively expensive. Companies in countries where the water supply is scarce or cannot be assured, should create their own water reserve (cistern), and sometimes may need a water truck fleet which, in practice, implies an increase in investment and production costs. In some countries, the water pumped from a well must pass through a sealed meter and the company pays the Government for each cubic metre pumped.

Although water costs used to be low in many countries (sometimes as a form of subsidy from the State), the current tendency is towards an increase in the cost of water as a consequence of the awareness of the worldwide drop in availability of this resource. At the same time, control of water sources is falling gradually into the hands of local Government (e.g., city councils) which are more conscious about actual water costs than central Governments. In this situation, variations can be found even within the same country for the cost of water, use policies and somewhat complex schemes according to the level of consumption.

For example, the fishery industry of Mar del Plata (Argentina) should pay a municipal water company every two months for the water consumed. Water costs depend on the actual level of consumption. Before being connected to the drinking water network, each fish company should present an estimate of its average consumption. If consumption is less than that estimated by the company, they only pay a flat rate. If consumption exceeds estimates, the excess is paid for in the following way: first 25% (Basic Price x 1.72), next 25% (BP x 2.13), 50% (BP x 2.92), 100% (BP x 5.35), etc. (first bi-monthly payment 1990). In addition, each factory is obliged to pay for a chemical analysis carried out weekly on its waste water. The costs of this analysis is US$ 6.6 (1990). If the result of this analysis is not satisfactory, another analysis is carried out a few days later. Repeating offenders may be required to pay fines. Table 4.8 shows the percentages that utilities (electricity, steam and water) represent of the total cost of production for the different types of fish plants.

Table 4.8

Costs of Utilities as Percentage of the Total Costs of Fish Plants

Type of Plant	% of Total Cost	Country	Data calculated from
Canning			
Sardines, mackerel	2.5	Argentina	(Zugarramurdi, 1981b)
Shrimp	1.4	Indonesia	(Bromiley *et al.*, 1973)
Tuna	2.2	"	"
Sardines (manual)	2.9	Tropical Countries	(Edwards *et al.*, 1981)
Sardines (mechanized)	7.3	Norway	(Myrseth, 1985)
Freezing			
Hake fillet	4.0	Argentina	(Parin *et al.*, 1990)
Shrimp	6.3	UK	(Graham, 1984)
Shrimp	10.1 (1)	USA	(Bartholomai, 1987)
Catfish	1.1	"	"
Fresh fish	0.9	USA	(Georgianna & Hogan, 1986)
Salting	0.1	Argentina	(Zugarramurdi, 1981b)
Drying (mechanical)	20.6	African countries	(Waterman, 1977)
" "	11.3	Brazil	(Vaaland & Piyarat, 1982)
Fishmeal	8.5	Argentina	(Cabrejos, 1969)
" "	11.3	Brazil	(Vaaland & Piyarat, 1982)
FPC, type B	14.4	"	"
FPC, type A	32.3	"	"
" "	28.9	USA	(Almenas, 1972)
Catch			
Wooden boats	29.3	Bangladesh	(Eddie & Nathan, 1980)
Motor boats	9.0	"	"
Purse Seiners	14.1	India	(Haywood & Curr, 1987)
" "	19.0	Thailand	"
" "	10.7	Morocco	"
Schooner (standard)	11.7	Seychelles	(Parker, 1989)
Schooner (special)	15.6	"	"
Schooner(new design)	20.4	"	"
Long-liners	26.2	Philippines	(Guerrero, 1989)

(1) Hydraulic conveyors used

For canning plants that use manual labour, expenses for utilities arise mainly from the consumption of fuel for the generation of steam; in mechanized fish canning plants utilities costs are mainly due to electricity consumption by equipment. As seen in Table 4.8, this percentage increases to 7.3% for a totally mechanized canning plant. Values for the mechanical drying process are not comparable because the cost of labour is higher in Brazil than in Africa. Fixed costs are similar, but variable costs (70%) in Africa are shared between raw materials (4.8%; Table 4.4), labour (1.4%; Table 4.6) and the remainder for utilities. Although when budgeting a project, utilities cost is estimated in a consolidated way (electricity, steam plus water) in analysing the cost structure of a plant, it may be necessary to disclose the various factors. In general, utilities account for less than 10% of the total cost of production in fish plants, while in catch, the price of fuel can push these values up to 30%.

4.2.5 Maintenance

This component includes the cost of materials and labour (direct and supervision) employed in routine or incidental repairs and, in some cases, the overhaul of equipment and buildings. Table 4.9 shows some reference maintenance costs as percentage of fixed investment.

Table 4.9

Costs of Maintenance as a Percentage of Fixed Investment (I_F)

	Costs of Maintenance as % of I_F	Country	Data calculated from
Freezing			
Sardines	2.6	Argentina	(Zugarramurdi, 1981b)
Shrimp	4	UK	(Graham, 1984)
Filleted and frozen	3	Senegal	(Jarrold & Everett, 1978)
Canning			
Sardines	2.6	Argentina	(Zugarramurdi, 1981b)
Tuna	3	Senegal	(Jarrold & Everett, 1978)
Tuna, Shrimp	2% Building	Indonesia	(Bromiley *et al.*, 1973)
" "	5% Equipment	"	"
Sardines	5	Tropical countries	(Edwards *et al.*, 1981)
Drying			
natural	6	African countries	(Waterman, 1977)
mechanical	2	" "	"
Fishmeal	1.6	Argentina	(Cabrejos & Malaret, 1969)
	3	Senegal	(Jarrold & Everett, 1978)
	3.3	USA	(Almenas, 1972)
Capture			
Artisanal			
Non-motorized canoes	2	Senegal	(Jarrold & Everett, 1978)
Canoes with fishing lines	3.1	Philippines	(Guerrero, 1989)
Canoe with awning	4.9	Seychelles	(Parker, 1989)
Boats with motor	5.7	Bangladesh	(Eddie & Natham, 1980)
Purse Seiners	2.4	Morocco	(Haywood & Curr, 1987)
Purse Seiners	2.1	Thailand	"
Catamaran	1.3	India	(Kurien & Willmann, 1982)
Canoe	1.5	"	"
Semi-industrial/Industrial	5	Senegal	(Jarrold & Everett, 1978)
Deep Sea Fishing Vessels	10	India	(Nordheim & Teutscher, 1980)
Hake vessels	5 (year 1)	Argentina	(Otrera *et al.*, 1986)
Purse Seiners with motor	20	India	(Kurien & Willmann, 1982)
Canoes with motor and line	15	"	"
Canoes with trawling nets	10.8	"	"

Maintenance is a critical factor in developing countries and two extreme situations can be found. The most typical situation is insufficient and sometimes complete lack of maintenance (even though it may be included in the original project) which works against self-sustained activities. In developing countries key equipment and even whole fish processing plants remain idle, due to lack of proper maintenance and small spares. The second situation, although much less common is over-maintenance, this means equipment that has exceeded a reasonable lifespan, and continues to be utilized. In the latter case there is the risk of utilizing less effective equipment (e.g., consuming more energy per unit of final product) and eventually resulting in a loss rather than a profit.

When no other data are available, maintenance costs can be estimated as 4-6% of fixed investment. This criterion, although commonly used, converts in practice, maintenance costs in a fixed cost, which is not completely correct.

A more appropriate estimate of maintenance costs can be made using the method proposed by Pierce (1948). If some basic costs and additional information are available equation (4.1) can be applied.

$$K = X \times (a + b \times y) \tag{4.1}$$

where: K = maintenance costs (US$/year)
X = annual consumption of electricity (kWh/year)
a = index for materials = costs of material for repairs per kWh used
b = index for labour = man-hours worked in repairs per kWh used
y = cost of man-hour with supervision.

It should be noted that the cost of maintenance increases as the equipment ages, but in these estimates average figures are used. This can be important for the economic evaluation of the investment, since the costs for the first years of operation will include a greater maintenance expenses charge. A new formula estimating maintenance costs is thus suggested, using a new value equal to the investment multiplied by the actual age of the equipment or installation.

$$I \times E$$

resulting in the formula:

$$M = A \times (I \times E) + B \tag{4.2}$$

where: M = Annual cost of Maintenance
I = Permanent Investment
E = Time elapsed (in years) since equipment was assembled whose investment is I

A and B are coefficients calculated based on historical values of similar plants. Unfortunately, few data are available to estimate these coefficients. For fish processing plants, an average value of A = 0.005 has been estimated. In the absence of other data, the value of B has been taken as 1% of fixed investment.

Krenkel *et al.*, (1968) proposed a formula for the calculation of maintenance for chemical plants, instead of using a percentage of fixed costs. This author proposes a correlation of maintenance costs against a parameter which denominates (investment - time), defined as:

$$(\text{Investment - time}) = I \times (E/n) \qquad (4.3)$$

where I and E have the same significance as given before, and n is the useful life of the equipment. This method could be used in highly mechanized fish processing plants.

For operational capacities lower than that installed, maintenance costs are generally estimated as 85% of total maintenance costs for a 75% operation capacity and 75% of total maintenance costs for a 50% level of production. In fishmeal plants, this component represents only 0.7% of the total cost of production and in frozen and canned fish plants it represents 0.8% and 0.3% respectively. From this, it can be deduced that maintenance costs never exceed 1% of the total cost of production. Therefore, as discussed earlier, the engrained tendency found in the fishery industry of many developing countries to avoid maintenance is mistaken unless other factors (e.g., lack of trained people to perform maintenance) prevail.

It is difficult to obtain data on repair and maintenance costs for fishing vessels. An alternative is to estimate using technical coefficients. Earlier, it was established that maintenance costs vary in proportion to the original value and age of the vessel. Based on this concept, Otrera and Gualdoni (1986), in estimating maintenance costs for deep sea vessels, propose using 5% of the initial value and a 4% increase annually to account for ageing, in the case of the hake fleet, since these values would adequately adjust actual values. For coastal fishing vessels, Parin *et al.* (1987b) found that 2% of the initial value and 4% annual increment would be close enough to actual values for repairs every four years and monthly servicing of the accounts of affidavits of remuneration of coastal fishermen, a share system to which fishermen contribute the costs of naval and mechanical work. Table 4.10 shows maintenance costs for each type of coastal vessel.

Table 4.10
Maintenance Costs by Type of Coastal Fishing Boats (Mar del Plata, Argentina)

Length (m)	Motor (HP)	Total Investment (*) (US$ '000)	Age (Years)	f_M (**)	Maintenance Costs (US$/year)
12-13.5	70-80	35-45	24-41	51-99	2 295-3 465
13.5-15	70-80	45-70	28-38	60-89	4 005-4 200
15-16	175	120-310	25-28	53-60	7 200-8 215
16-18.5	380	180-240	25-41	53-99	12 720-17 820
18.5-21	380	240-300	8-13	27-33	5 520-8 100

(*) Cost of investment in boat and nets
(**) Annual maintenance factor x 10^3

4.2.6 Supplies

Except for those included in raw materials, or repairing and packaging materials, this component includes all materials used by the industrial plant, such as lubricating oils, chemical reagents, laboratory glassware and soap for can washers. This item can be estimated as 6% of the costs of labour and 15% of maintenance costs (Woods, 1975).

4.2.7 Royalties and patents

Any production licence to be paid for based on units produced must be considered a component of variable costs. This is not an usual situation in the fishery industry; it could change with aquaculture development and application of bio-engineering. Generally, the licence fee is paid according to a pre-determined volume of production. In the absence of other data, it can be estimated between 1% and 5% of the sale price of the product in question.

4.2.8 Packaging

This component is usually considered part of the raw material costs but it is preferable to detail it separately, as in some instances in the fishery industry it constitutes a very important part of the total production costs. Table 4.11 shows percentages of cost of packaging for fish processing plants. Packaging costs are generally high in canning plants. However, costs for canning in Norway are surprisingly low, far from the average values encountered for this component (this in turn could be linked to low energy costs in Norway). A similar case is found in the packaging costs for standard frozen products, but the variation here results from the prices paid for different raw materials. In turn, this influences the type of product, as a higher packaging cost would be involved in the production of headed and eviscerated fish than of fillets. Appendix C5 lists actual costs for tin plate cans and other packaging.

Table 4.11
Costs of Packaging as a Percentage of the Total Cost of Fish

Type of Plant	% of Total Costs	Country	Data calculated from
Canning			
Sardines	6	Norway	(Myrseth,1985)
Anchovy-mackerel-tuna	23-41	Argentina	(Zugarramurdi,1981b)
Sardines	40.9	Tropical Countries	(Shaw,1976)
Tuna	18.6	Indonesia	(Bromiley *et al.*, 1973)
Shrimp	19.4	"	"
Freezing	2-6	Argentina	(Parin *et al.*, 1990)
Shrimp	6.6	U.K.	(Graham, 1984)
Hake, fish block	5.1	Uruguay	(Kelsen *et al.*, 1981)
White croaker H&G	12.2	"	"
Striped weakfish IQF	6.0	"	"
Catfish (live)	0.2	USA	(Bartholomai, 1987)
Shrimp	2.1	"	"
Fresh, sole	2.6	"	(Georgianna & Hogan, 1986)
Salting of anchovy	15	Argentina	(Zugarramurdi, 1981b)
Fishmeal	2.8	"	(Cabrejos & Malaret, 1969)

4.3 Fixed Costs

4.3.1 Indirect costs

4.3.1.1 Investment costs

Depreciation: means a reduction in value. Most goods decrease in value as they increase in age. Production equipment recently acquired has the advantage of the latest refinements and operates with less risk of breakdown or need for repairs. Except for a possible antique value, production equipment gradually becomes less valuable with use. This loss in value is recognized in accounting practice as an operating expense. Instead of charging the entire value of a new asset as a one-time expense, the usual practice is to distribute the purchase cost in the accounting ledgers, over the useful life of the asset. This concept of depreciation may seem to conflict with the actual cash flow for a particular transaction, but when all the transactions are seen collectively, they form a realistic picture of the consumption of capital in profit and loss situations.

In financial accounting, depreciation is an indirect cost. The main objectives in charging a depreciation cost can be summarized, to: 1) recover capital invested in production equipment, 2) enable accurate calculation of indirect production costs for recording purposes, and 3) include costs of depreciation in operational expenses for tax purposes.

The importance of depreciation should be stressed particularly at artisanal and small-scale industrial level. Countries and institutions receiving equipment and plants as external aid for development must be aware that they should plan their operation such that depreciation could be effectively considered, otherwise self-sustainability will not be achieved. To emphasize the importance of depreciation, the following can be considered:

Example 4.2 The Importance and Meaning of Depreciation

The inhabitants of Jakuna Matata, a fishery village on the coast of Ruritania, have a very serious problem. The ice plant that provided ice to the fishermen during the last four years is broken and the cost to fix it is equivalent to that of buying a new plant, but they do not have enough money for this. Four years ago when the ice plant was delivered to the fishermen, it was a feast day for Jakuna Matata people. The Minister of Fisheries of Ruritania and the Ambassador of the country that donated the US$ 10 000 ice plant were there. Fishermen were badly in need of the ice plant to be able to sell their fish in the capital of Ruritania or to keep the fish in the right condition till the trucks from the middlemen arrived in Jakuna Matata.

The fishermen organized themselves and collectively decided to set a price on the ice in order to cover the electricity costs and the salaries of two men to run and care for the ice plant plus a small profit just to cover ice losses and unexpected expenditures. Ice prices were very low, lower than the price paid in the capital city and the fishermen were very happy. During the first two years there were no problems and the plant worked for nearly 300 days a year. When the first breakdown occurred, fortunately there were funds available from the small profits to pay for the spare parts and the mechanic who came to fix the plant. The savings were not high, about US$ 5 per working day, but enough to pay for the first expenditure. Nevertheless, not all the money that should have been there was available; part of it had been used for village festivities and some had been lent to fishermen in need who had not returned it. Despite this, there was sufficient money to pay for the first breakdown and it taught the lesson that savings were necessary.

Repairs were also necessary during the third and fourth years of functioning of the ice plant and people realized that operations would not be so straightforward as during the first two years. However, towards the end of the fourth year, the ice plant stopped and the mechanic that came from the capital city informed them that this time the damage was very serious and that repair would cost the same as buying a new ice plant. The fishermen realized that they had not saved enough to pay for such a large repair job or to buy a new ice plant at the end of the lifespan of the one they received as a gift. What had happened?

The fishermen had not considered depreciation in their calculations and no provision for recovering the capital invested in the ice plant (US$ 10 000). Its initial value of US$ 10 000 depreciated until its residual value was zero. By not including depreciation they were also utilizing the initial capital of US$ 10 000 to produce ice and to produce (or so it appeared) large profits and extra benefits for the fishermen. Actually, it was a production cost, similar to raw material and energy costs. However, depreciation differs from these costs in that it is always paid or provided for in advance. Consequently, it is essential that depreciation be taken into account so that the capital used to provide for this cost can be recovered. If this is not done, the final result will be the exhaustion of the capital, as happened to the fishermen of Jakuna Matata (and unfortunately to many other artisanal fishermen worldwide). By not calculating depreciation they failed to produce a sustainable situation even when all the other factors were in order.

Please discuss the case. The fishermen of Jakuna Matata were thinking of asking for a new ice plant from the donor country and resolved not to repeat the same mistake. Analyse in this case, other aspects that could come into the picture like the existence of banking facilities (for saving), inflation and the actual possibilities of the fishermen to obtain hard currency and import machinery.

In studying depreciation, it is helpful to visualize a depreciation charge as a series of payments made to a specific fund to replace an asset which is still being used. While this notion is completely acceptable in theory, it is rarely practised in industrial contexts. An accounting ledger shows the annual depreciation charge used for taxation purposes, but it also appears in the accounts with "Other Assets" such as working capital.

The physical form of the "depreciation fund" can take very different forms, for instance it can be a revolving stock of raw material or finished products (often used in the frozen and canning fishery industry), treasure bonds, time-deposits, secured deposits and sometimes land (when it can be sold easily). In the artisanal fisheries of many developing countries, actual "depreciation funds" can be gold and silver jewellery that fishermen buy for their wives and daughters (or that women, engaged in fisheries, buy themselves).

The original cost of the asset less the accumulated depreciation, is called the Net Book Value. Land is one of the few assets which does not need a depreciation reserve, as its value normally remains the same or increases.

Depreciation is not an easy concept. Therefore, the fish technologist should know, in each case, the causes for loss of value of equipment and machinery. Knowledge of the potential causes of a decrease in value of an asset can help determine the most appropriate means of depreciating it. Possible causes of depreciation are:

(a) Physical Depreciation: Break-down due to daily use of equipment gradually reduces its physical ability to carry out its function. A good maintenance programme retards the speed of decline, but it is difficult to maintain the precision expected from new equipment. Added to normal use, accidental physical damage can also reduce output.

(b) Functional Depreciation: Demands made on an item can exceed its production capacity. A central heating unit, not built to satisfy increased demand for heat resulting from the addition of a new building, will not provide more than its specific capacity. In the other extreme, demand for a machine's services may cease during its existence, as can happen with a machine that produces a product for which there is no longer any demand.

(c) Technological Depreciation: The development of new methods to carry out a function may render current methods uneconomical. For example, steam engines rapidly decreased in value with the advent of the Diesel engine. The current style for a product, new materials, improvements in safety and better quality at lower cost, due to new developments, renders old designs obsolete.

(d) Depletion: The consumption of a natural exhaustible (non-renewable) resource in the production of goods or services is called depletion. The extraction of petroleum, wood from tropical forests, rock or minerals from a place diminishes the value of the unexploited resource. This reduction is compensated for by a proportional reduction in earnings derived from the resource. In theory, the depletion charge per unit of resource extracted is:

$$\frac{\text{Current Value of the Resource}}{\text{Remaining Units of the Resource}} = \text{depletion rate (US\$/unit)}$$

Fish is a natural renewable resource. However, current fish stocks have an MSY (Maximum Sustainable Yield), above which overfishing and depletion are risked.

(e) Monetary depreciation: Change in price is one problem which causes decreases in value of the depreciation reserves. Usual accounting practices calculate depreciation based on the original price of the item and not on the new price. However, because of the high rate of inflation, revaluation is allowed for tax purposes.

4.3.1.2 Methods of Calculating Depreciation Costs

Four methods of calculating depreciation rate are normally used: Straight Line, Declining Balance, Sinking Fund and Sum of the Year's Digits. All these methods are based strictly on time; that is, an asset used every day has the same depreciation charge as one used only once a year.

Each depreciation calculation method has unique characteristics which make it attractive to different types of administrative philosophies. For tax purposes, however, the one recognized by law should be used. For example, in Argentina, this is the Straight Line method; and from 30 December 1968 accelerated depreciation was permitted in specific cases (due to monetary depreciation by inflation).

A method through which the total amount of capital invested can be recovered early in the life of an asset is a popular and conservative concept. Early settlement guards against sudden changes which can make the asset lose value, and transfer some taxes to later years. However, methods in which the annual charge is constant simplifies accounting procedure.

In general, it is desirable that a depreciation method: 1) recovers the capital invested in an asset; 2) maintains a book value near the real value of the asset throughout its lifetime; 3) is easy to apply and 4) is acceptable by law. In reality, there are two aspects relating to application of the methods of depreciation: the internal company aspect, through which the method which the management considers most appropriate is applied and the tax aspect, where the method assigned by law, must be applied.

In general, the annual amount of depreciation, is given as:

$$\text{Annual depreciation value} = e \times (I_F - L) \tag{4.4}$$

where:
e = rate of depreciation for company purposes of calculating profit
$I_F - L$ = depreciable investment
I_F = initial fixed capital investment
L = salvage or scrap value at the end of the useful life of an asset

The term salvage or scrap value implies that the asset can give some type of further service. If the property cannot be disposed of as a useful unit, it can often be dismantled and sold as junk to be used again as manufacturing raw material. The profit obtainable from this type of disposal is known as the scrap or junk value.

The residual value cannot be predicted with absolute accuracy, so it is advisable to make new estimates from time to time during the service life of the depreciation costs (Peters and Timmerhaus, 1978). All methods used to calculate the rate of depreciation compute it as a function of time; i.e., an asset used every day has the same depreciation charge as one used only once a year.

The straight line method; the simplest and most widely used, is explained below; annual depreciation is constant and the relationship is:

$$e = \frac{1}{n} \tag{4.5}$$

where n is the total expected useful life in years. Therefore, applying Equation (4.4), the annual depreciation charge is:

$$D = \frac{(I_F - L)}{n} \tag{4.6}$$

For any arbitrary year, the k^{th} year, depreciation is:

$$D_k = (I_F - L) \times \frac{k}{n}$$

The book value is the difference between initial investment and the product of the number of years of use multiplied by the annual depreciation charge; the book value at the end of k year, B_k, is:

$$B_k = I_F - k \times D = I_F - k \times (I_F - L)/ n \qquad (4.7)$$

Depreciation costs are calculated according to the straight line method. Various references give detailed descriptions of the other depreciation methods (Riggs, 1977; Barish and Kaplan, 1978; Happel and Jordan, 1981).

Property taxes: This component can vary widely according to current laws. Basically, taxes depend on the location of the plant, and thus plants located in cities pay more taxes that those in less populated areas.

Taxes on earnings are not included here. In the fishery industry, this component is calculated as a percentage of investment, with values which do not usually exceed 2%. If local value of property taxes is not available, 1-2% of the I_F can be used as the first basis of calculation.

Insurance: This depends on the type of process and possible need of protective services. Normally insurance is bought on property (fire, partial or total theft), for personnel and merchandise (partial or total loss), drop in wages, etc. In capture, the percentage paid for insurance is higher, as indicated in Table 4.12.

Table 4.12
Costs of Insurance in the Fishery Industry and in Capture

Activities	% of I_F	Country	Data calculated from
Fish capture	3	Peru	(Engstrom *et al.*, 1974)
Fish capture	3.5	India	(Nordheim & Teutscher, 1980)
Fish capture	3.5	Seychelles	(Parker, 1989)
Fish processing (general)	1-2	Argentina	(Zugarramurdi, 1981b)
Fish canning	2	Indonesia	(Bromiley *et al.*, 1973)
Fish canning	1	Tropical Countries	(Edwards *et al.*, 1981)
Fish freezing	2	UK	(Graham, 1984)
Fishmeal	2	USA	(Almenas, 1972)

The tendency in developing countries, particularly at medium and small scale level is to avoid paying insurance. This is compounded in many places by the lack of insurance companies at local level that want to sell insurance on fishing boats and small enterprises, social unrest, civil wars, high inflation in local currency and difficulties in having insurance paid in case of accident. This situation, when it exists, plays against sustainability.

Credit financing: Interest is compensation paid for the use of borrowed capital. On seeking credit, a fixed or adjustable interest rate is established according to the economic circumstances of the country. This interest is a fixed cost to be paid when a loan or bank credit is requested to make a full or partial investment. Even so, many insist that interest should not be regarded as a production cost since it can be considered as part of the earnings of a business. This is due to the fact that a company's earnings would depend on the source of capital employed.

Therefore, a plant which is run more efficiently and uses borrowed capital, will have higher production costs and lower earnings than one of the same size and type which operates under less efficient conditions, but which uses its own capital.

The essence of the discussion is whether or not "earnings" include interest as part of the costs. If the interest is deducted from total capital (own and borrowed), the remaining difference will represent earnings. However, for taxation purposes, the laws generally consider earnings as the difference between income from sales (net earnings) and total costs without taking account of interest on the capital belonging to the company. Thus, unless otherwise specified by law, interest paid on a loan bank credit or financial credit by suppliers (e.g., on machinery) should be considered a fixed cost.

Other obligations: This includes rent (when the land and/or building or even equipment is rented), contributions, etc.

4.3.1.3 General expenses

In the fishery industry, these costs are a small part of the total costs of production (approximately 1%) and are usually estimated in conjunction with investment costs.

4.3.1.4 Global estimate of indirect costs

When a quick estimate has to be made, these costs can be calculated together as a percentage of the direct costs of manufacture, using coefficients given in Table 4.13, which were generally evaluated for the fishery industry.

Table 4.13
Indirect Costs for Fish Processing Plants

Type of Plant	Indirect Costs % of Direct Costs	 % of Total Cost of Production	Country	Data calculated from
Canning, Sardines	10-12.5	8-10	Argentina	(Zugarramurdi, 1981b)
Freezing	17-20.0	14-16	"	"
"	13.9	10.8	UK	(Graham, 1984)
Salting of anchovy	16.8-19.7	14-16	Argentina	(Zugarramurdi, 1981b)
Fishmeal	12.5	11.8	"	(Cabrejos & Malaret, 1969)
FPC	16.0	13.6	USA	(Almenas, 1972)

4.3.2 Management and administration costs

Some authors propose an estimate of 40% of direct labour for this component. However, when estimating this component as percentages of direct production costs for the fishery industry, values in Table 4.14 can be used (Zugarramurdi, 1981b).

Management and administration costs usually include the costs of all the services related indirectly to production, for example:

- Quality Control Laboratories
- Medical and Hospital Service

- Security (e.g., premises, stored goods)
- Cafeteria
- Administration: Salaries and General Expenses
- Communications and Transport within the Plant
- Safety (in working places)
- Legal Advice
- Audits
- Recall Service (large firms)

Table 4.14
Management and Administration Costs for Fish Plants

Type of Plant	% Direct Costs	% Total Costs	Country	Data calculated from
Canning				
Sardine and mackerel	5-7.5	4-6	Argentina	(Zugarramurdi, 1981b)
Tuna	5	-	Senegal	(Jarrold & Everett, 1978)
Tuna	8.5	6	Indonesia	(Bromiley *et al.*, 1973)
Shrimp	2.1	1.8	"	"
Sardines	8.8	4.85	Tropical Countries	(Edwards *et al.*, 1981)
Freezing	3.9	3.2	Argentina	(Zugarramurdi, 1981b)
Shrimp	12.6	9.8	UK	(Graham, 1984)
Salting	2.6	2.1	Argentina	(Zugarramurdi, 1981b)
Fishmeal	3.2	1.7	"	(Cabrejos & Malaret, 1969)

4.3.3 Sale and distribution costs

This component usually includes:

- Salaries and General Expenses in Sales Offices
- Salaries, Commissions and Travel Expenses for Employees in Sales Department
- Shipping and Transport Expenses
- Extra Expenses associated with Sales
- Technical Services for Sales
- Preparation and Shipment of Samples to Potential Purchasers
- Participation in Fairs
- Promotion Costs in General

In general, this cost is usually approximated as 1% of total sales. In the case of fish plants, values in Table 4.15 can be used.

Table 4.15
Sale and Distribution Costs for Fish Plants

Type of Plant	% Direct Costs	% Total Costs	Country	Data calculated from
Canning				
Sardine and mackerel	2.5-12.5	2	Argentina	(Zugarramurdi, 1981b)
Shrimp	0.9	0.8	Indonesia	(Bromiley *et al.*,1973)
Tuna	2.4	1.8	"	"
Freezing	1.0	0.8	Argentina	(Zugarramurdi, 1981b)
Salting	0.9	0.7	"	"
Fishmeal	0.6	0.5	"	(Cabrejos & Malaret, 1969)

4.3.4 Global estimate of fixed costs

From the values given before (see section 4.3), it is possible to estimate the values given in Table 4.16 which allow the approximate Total Fixed Costs for a fish processing plant to be estimated.

Table 4.16
Fixed Costs for Fish Plants

Type of Plant	% Direct Costs	% Total Costs	Country	Data calculated from
Canning				
Sardine and mackerel	22-29.5	18-22	Argentina	(Zugarramurdi, 1981b)
Tuna	18.5	14.5	Indonesia	(Bromiley *et al.*, 1973)
Shrimp	11.4	10.2	"	"
Sardines	11	10.2	Tropical countries	(Edwards *et al.*, 1981)
Freezing	22-25	18-20	Argentina	(Zugarramurdi, 1981b)
"	22.8	22.4	UK	(Graham, 1984)
Fishmeal	16.3	14	Argentina	(Cabrejos & Malaret, 1969)
FPC	18.5	15.5	USA	(Almenas, 1972)
"	23.8	19.3	Brazil	(Vaaland & Piyarat, 1982)
Salting	22.7	18.5	Argentina	(Zugarramurdi, 1981b)

4.4 Case Studies on Production Costs

4.4.1 Icing costs utilizing insulated containers

In tropical developing countries, the only economically viable possibility of introducing ice in fisheries, is introducing insulated fish containers together with ice. Depending on the case, even insulated containers may not be a sustainable choice. However, the option to insulate containers plus ice, a cold chain with refrigerated trucks and chilling rooms will be more expensive and probably less sustainable. In order to make a proper analysis of production costs of icing, it should be taken as an activity in which equipment (the insulated container, fixed costs) is operated by a worker (labour cost), who introduces ice (raw material) into the container, in order to create a finite volume where a given amount of fish will be kept at about 0°C. This means that in this operation, three basic elements are needed to determine the icing processing cost (IPC):

$$\text{IPC} = (\text{fixed costs}) + (\text{ice cost}) + (\text{labour cost}) \qquad (4.8)$$

The fixed cost will be in this case basically the depreciation cost. Therefore, according to the section on depreciation (p. 111):

$$(\text{fixed costs}) = e \times (I - L) \qquad (4.9)$$

where: e = annual depreciation value (1/expected lifespan)
I = depreciable investment (the cost of the container)
L = residual value (in case of fish boxes and containers $L = 0$)

In the case of fish boxes and insulated containers, it is customary to count lifespan according to the number of times the box or container is utilized. This criterion can be considered equivalent to the annual depreciation value and it is easier to understand particularly at the artisanal level. Therefore, fixed costs can be expressed in this case as:

$$\text{(fixed costs)} = I/N \tag{4.10}$$

with: N = expected number of times the container will be used

In the same way:

$$\text{(ice cost)} = c_i \times M^o_i \tag{4.11}$$

$$\text{(labour cost)} = c_w \times t_{fh} \tag{4.12}$$

where: c_i = price of ice (US\$/kg)
c_w = cost of labour (US\$/man x hour)
M^o_i = initial mass of ice in the container (kg)
t_{fh} = working time to fill in a container with fish and ice (hours) (t_{fh} should incorporate transport time within the plant, washing if necessary, dead and waiting time and any other time linked with the operation)

Replacing (4.10), (4.11) and (4.12) in (4.8) the following is obtained:

$$IPC = (I/N) + c_i \times M^o_i + c_w \times t_{fh} \tag{4.13}$$

Expression (4.13) can be used to estimate the icing cost (one operation with a given container). However, as with other equipment, it is more useful to express the results per 1 kg of final product. In this case, the final product is the amount of fish chilled and kept at O°C in the insulated container (M_f). Dividing both parts of (4.13) by M_f gives:

$$IC = I/(N \times M_f) + c_i \times (M^o_i/M_f) + c_w \times (t_f/M_f) \tag{4.14}$$

where:

IC = Icing costs per 1 kg of fish kept in the container (US\$/kg of fish).

Equation (4.14) allows introduction of the capacity factor. In the way that, for instance, a fish filleting machine will be evaluated according to the number of fish it can process in a given period (because it is related to production cost) an insulated container should be evaluated according to the amount of fish it can keep each time it is used. In an insulated container the useful volume is divided between fish and ice according to:

$$V_c = M^o_i \times V_{si} + M_f \times V_{sf} \tag{4.15}$$

where: V_c = internal (useful) volume of the insulated container (cm^3)
V_{si} = specific volume of ice utilized (cm^3/kg)
V_{sf} = specific volume of fish stowed in the container (cm^3/kg)

Equation (4.15) assumes that the container is fully loaded with ice and fish (which in most cases is a normal situation). As the fish to ice ratio is:

$$n = M_f/M^o_i \tag{4.16}$$

from where: $$M_f = n \times M_{oi} \tag{4.17}$$

or: $M^{o}_{i} = M_f/n$ (4.18)

replacing (4.18) in (4.15) gives:

$$V_c = M_f \times (V_{sf} + V_{si}/n) \qquad (4.19)$$

or:

$$M_f = \frac{V_c}{V_{sf} + (V_{si}/n)} \qquad (4.20)$$

Replacing equation (4.14) by equations (4.16) and (4.20) gives:

$$IC(N) = \frac{I}{N \times V_c} \times \left(V_{sf} + \frac{V_{si}}{n}\right) + c_i \times \frac{1}{n} + c_w \times \frac{t_{fh}}{V_c} \times \left(V_{sf} + \frac{V_{si}}{n}\right) \qquad (4.21)$$

The type of container and the conditions will influence IC(N) through V_c, n and N (durability). The value of n can be obtained from the calculations presented in Chapter 2 of this manual. In general, Equation (4.21) is represented in Figure 4.6.

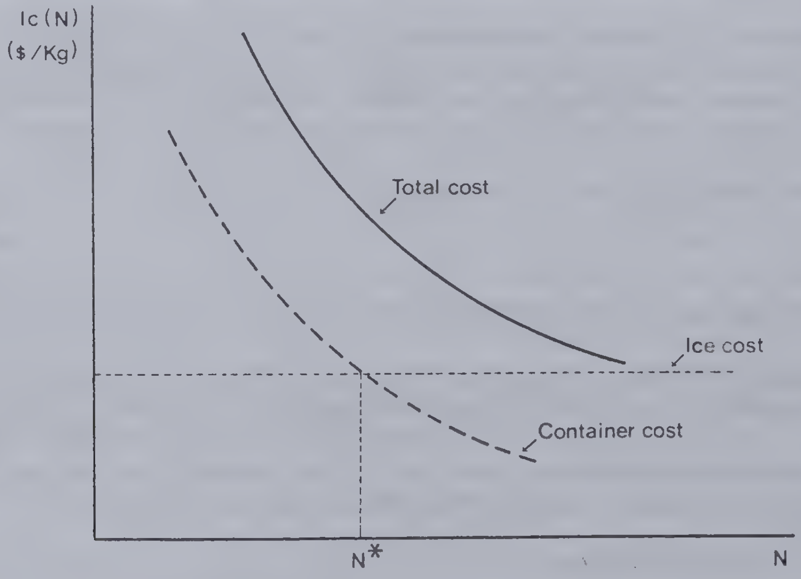


Figure 4.6 Scheme of the Ice Costs Variation vs the Number of Times the Container is Utilized

As can be seen, IC(N) will decrease with the increase in the number of times the same container (N) is utilized. If the container lasts long enough, the final costs of icing are determined by the cost of ice. The same happens if the cost of the container is negligible compared with the ice cost. N* in Figure 4.6 indicates the number of times when fixed costs equal ice costs plus wages. Above N* the relative cost of ice will be higher than the relative costs of the container. It can be seen that the fish to ice ratio will affect the incidence of the relative cost of wages. The higher the fish to ice ratio, the lower the relative incidence of wage costs for icing.

Example 4.3 Calculate Icing Costs in Developing Countries

Compare the value of fish to ice ratio (n) and the icing costs in different countries, using the situations defined in Example 2.12 (wage costs are not considered in this calculation). With: m = number of containers iced per hour = 3; t_{fh} = 0.33 h

Table 4.17
Data for Developing Example 4.3

Country	Paraguay	Trinidad & Tobago		Denmark
Type of container	(1)	(2)	(3)	(4)
Cost of container (in US$/kg)	26.15	7.3	130	70
Ice cost (US$/kg)	0.099	0.11		0.017
Fish cost (US$/kg)				
Characin (*Prochilodus scrofa*)	0.27	-		-
Jaw characin (*Salminus maxillosus*)	1	-		-
Snapper	-	3.26		4.5

(1) Styrofoam, (2) Styrofoam, insulated, (3) Insulated (rubber), (4) Metabox 70

Answer: Using the data provided in this example, values in Table 4.18 are obtained.

Table 4.18
Optimal Utilization of Containers in Different Climatic Conditions

Country	Paraguay	Trinidad & Tobago		Denmark
Type of container	(1)	(2)	(3)	(4)
M_f/M_i, characin (*Prochilodus scrofa*)	1.57 (19.27/12.27)	-	-	-
M_f/M_i, jaw characin (*Salminus maxillosus*)	1.56(19.00/12.18)	-	-	-
M_f/M_i, snapper		0.71(8.31/11.82)	1.32(16/12.16)	6.48
Value ice/value fish (in %)				
Characin (*Prochilodus scrofa*)	23.3%	-	-	-
Jaw characin (*Salminus maxillosus*)	6.3%	-	-	-
Snapper	-	4.8%	2.6%	-
N*	21.4	5.65	77.12	434

Table 4.18 shows that the relative cost of ice in developed temperate countries is so low compared with other costs that the fish to ice ratio can be varied without introducing great changes. In tropical countries the relative cost of ice is sometimes so high that a variation in n will introduce wide variations in the total cost. The main concern in this type of country should be the increase in the fish to ice ratio (n). From Table 4.18 it is clear that the N* value is generally reached more rapidly in developing countries than in developed countries (i.e., the savings on ice would pay for the investment cost rather quickly).

The cost of the container (locally made or imported) cannot be a valid deterrent to the introduction of insulated containers in most developing countries provided they have the proper insulation and allow for tangible savings on ice and increased earnings due to quality and prevention of post-harvest losses. If wage costs are introduced in the calculations, the main factor will usually be the wage cost in developed countries whereas in developing countries it will be the ice cost.

This means that the main objective in reducing icing costs in developed countries will be (and actually is) to increase productivity, e.g., to introduce a special chute to handle ice, a special table to handle and move containers, an automatized weighing and mixing device for fish and ice, whereas in developing countries it should be to rationalize the ice consumption as far as possible (Lupin, 1985 b). Utilizing actual values, it has also been found that a 20-times difference in wage cost cannot offset a 10-times difference in the cost of ice. In this case, the "comparative advantage" of developing countries in having low manpower cost is lost when the ice cost factor is taken into consideration (Lupin, 1985 b). This case underlines the need for cost analysis as an essential tool to identify concrete development needs and define the type of technology and procedures to be pursued.

In some tropical developing countries it is possible to find large and expensive locally-made metallic containers. Although they are costly probably the incidence on the costs per 1 kg of iced fish is negligible after a year or so. Moreover, the containers tend to be large in order to reduce the area/volume ratio that in turn will decrease ice losses and increase the fish to ice ratio. Fishermen may not know about the fish to ice ratio or cost calculations, but they certainly tend to optimize from experience. As found elsewhere the costs of the container are quickly paid for by the savings on ice in tropical conditions (Villadsen *et al.*, 1979).

4.4.2 Capture costs for coastal fishing vessels

An analysis of the values for capture costs given in the literature on the subject shows that the variables which have most influence are: type of fishing vessel, fishing gear used, price of fuel, species to be caught (seasonal or yearly), efficient use of the fish hold.

Figure 4.7 is presented as an example and shows the proximal distribution of the capture costs for coastal fishing vessels in Argentina, estimated in accordance with the basic method proposed (sections 4.2 and 4.3). The results of Figure 4.7 are typical of artisanal fish processing in which a large proportion of costs is labour (crew plus the owner who is usually the master fisherman) and, therefore, profits are relatively low.

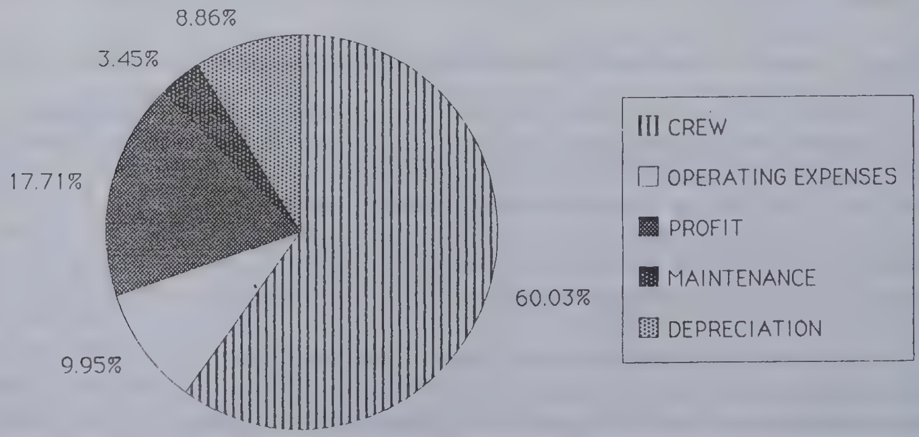


Figure 4.7 Proximal Distribution of Production Costs in Capture (Coastal Fishing Vessels, Argentina, Parin *et al.*, 1987b)

In case 4.4.1, the basic cost structure was combined with the technical aspects to develop an analysis of the situation. In case 4.4.2, the basic cost structure was applied to obtain a classic result.

4.5 Model for Estimating Production Costs in Fish Plants

When analysing production costs schemes it is useful to be able to make quick estimates on changes in one or more variables and/or to study the relationship between variables in order to determine production policies.

In analysing the methods for estimating operational costs in fish processing, it emerges that a satisfactory means of evaluating them is to consider five main variables (Parin and Zugarramurdi, 1987), devising an equation such as the following, for each productive process, using total capacity:

$$TC = \mathbf{a} \times R + \mathbf{b} \times L + \mathbf{c} \times E + (\mathbf{d}+\mathbf{m}) \times (I_F/Q) \tag{4.22}$$

where: TC = total unit cost (US\$/unit of production)
R = cost of raw material (fish) (US\$/unit)
L = cost of direct labour (US\$/unit)
E = cost of services (US\$/unit)
I_F = fixed investment (US\$)
Q = plant capacity (Units/year)

It can be observed that:

a	indicates the relationship of total costs of raw material, including fish packaging, ingredients, etc. and R;
b	indicates the relationship between total costs of direct and indirect labour (general, administrative and supervision costs) and L;
c	indicates the relationship between effluent and other services and the direct costs of steam, water and electricity, affecting production;
d	indicates the relationship between depreciation costs, insurance, taxes and I_F/Q;
m	indicates the relationship between maintenance costs and I_F/Q.

The analysis of the coefficient **a** is especially important, as it indicates the proportion between the costs of the product with and without packaging. In canning plants, for example, the costs of the can are generally high when compared with that of raw material, reaching values close to or above 2, in the majority of the cases studied.

According to the methodology proposed, coefficient **a** considers not only packaging, but also ingredients. Thus a coefficient value slightly higher than 2 would indicate that the consumer is still receiving in proportion a greater quantity of raw material than packaging for the same price.

Table 4.19 shows the coefficients obtained for different fish processing plants, using equation (4.22).

Table 4.19
Estimate of Production Costs of Fish Plants

Type of Plant	a	b	c	(d+m)	References
Canning plant					
- Sardines, manual	3.00	2.23	1.05	0.228	(Zugarramurdi & Parin, 1987a)
- Mackerel, manual	1.88	2.22	1.05	0.253	"
- Hake, manual	2.17	2.22	1.05	0.249	"
- Tuna, manual	1.30	2.22	1.05	0.237	"
Freezing plant					(Parin *et al.*, 1990)
- Hake, fillet, manual	1.15	1.77	1.05	0.147	"
- Hake, H&G, manual	1.20	1.96	1.05	0.147	"
- Kingklip, fillet, manual	1.08	1.65	1.05	0.147	"
- Shrimp, manual	n/a	1.60	1.05	0.148	"
- Shrimp, mechanical	1.09	2.41	1.05	n/a	"
- Catfish, mechanical	1.06	2.27	1.05	n/a	"
Salting plant (*)	1.035	1.62	1.035	0.168	(Zugarramurdi, 1981b)
Fishmeal plant (*)	1.038	1.66	1.038	0.167	"

(*) In this case, coefficient **a** was calculated with R including raw material and packaging

Table 4.20 shows some values of **a** that were obtained from food canning plants; it is seen that in the case of sardines in oil the consumer receives a greater proportion of packaging than raw material, even in the larger volume cans. This is not the case with hake, which in the 380 g can, succeeds in reaching a coefficient value of **a** near to 2. A coefficient value of 2.04 was registered in a Norwegian plant (sardines); the corresponding value from tropical countries was 3.47, exceeding all similar values recorded in Argentina.

Table 4.20
Coefficients **a** for Fish Canning Plants

Type of Product		Coefficient **a**	Country	References
Canned fish				
Sardines,	115 g	3.34	Argentina	This work
"	170 g	3.00	"	"
"	260 g	2.69	"	"
Mackerel,	380 g	1.88	"	"
Hake,	190 g	2.72	"	"
"	380 g	2.17	"	"
Tuna,	190 g	1.30	"	"
"	330 g	2.26	"	"
Sardines,	115 g	3.47	Tropical Countries	(Edwards *et al.*, 1981)
"	"	2.04	Norway	(Myrseth, 1985)

Thus, the value of the coefficient **a** can be correlated to the relative prices of fish (R/TC), in order to analyse the possibilities of export and the type of modifications that will be required in the cost structure in order to reduce costs. From the relationship R/L can be defined the incentives policy to be followed. The greater the value of this relationship, the more advisable it will be to pay incentives to the work force.

From Tables 4.19 and 4.20 it is clear that coefficients of equation (4.22) should be determined for each particular case. However, coefficients in Table 4.19 and 4.20 can be used for first estimates when actual values are not available.

Example 4.4 Calculation of Production Costs for a Fish Frozen Plant

Calculate the production costs to elaborate frozen skinless fillet blocks for the frozen fish plant of Example 2.1.

(a) Component by component

(b) From the coefficients given in Table 4.19

Answer:

(a) Operating costs are commonly calculated on one of three bases: unit-of-product, daily or annual. First, it will be calculated the unit-of-product cost expressed as US$ per unit of end product. Daily production is 2 t of frozen fish blocks (FB).

- Raw Material :

Fish

Amount of raw material = 5.9 t hake/day (from Example 2.3)
Price of raw material = 235 US$/t hake (from Appendix C2)

$$\text{Cost of Fish} = \frac{\text{Amount raw material (t hake/day) x Price (US\$/t hake)}}{\text{Production fillet blocks (t FB/day)}} =$$

$$= \frac{5.9 \text{ x } 235}{2} = \text{US\$ } 693.2\text{/t FB}$$

Packaging:

Amount of waxed cartons = 300 cartons (from Example 2.17)
Price of waxed boxes = US$ 0.26 (from Appendix C5)
Amount of master boxes = 100 boxes (from Example 2.17)
Price of master boxes = US$ 0.5 (from Appendix C5)
Straps and labelling cost = US$ 4/t FB

$$\text{Cost of waxed cartons} = \frac{\text{Amount waxed cartons (cartons/day) x Price (US\$/carton)}}{\text{Production fillet blocks (t FB/day)}} =$$

$$= \frac{300 \quad x \ 0.26}{2} = \text{US\$ 39/t FB}$$

$$\text{Cost of master boxes} = \frac{\text{Amount master boxes (boxes/day) x Price (US\$/box)}}{\text{Production fillet blocks (t FB/day)}} =$$

$$= \frac{100 \quad x \ 0.5}{2} = \text{US\$ 25/t FB}$$

Cost of Packaging = Cost of cartons + Cost of boxes + Cost of Straps & Labelling =
= 39 + 25 + 4 = US\$ 68/t FB

Cost of Raw Materials = Cost of Fish + Cost of Packaging =
= 693.2 + 68 = US\$ 761.2/t FB

- Labour:

Direct Labour (DL) :

Filleters

Amount of Filleters = 15 (from Example 2.13)
Basic salary: US\$ 0.06/kg fillet (from Appendix C3)
Social charges: 70% (Argentina, 1991)

Cost of Filleters =
= Basic salary (US\$/kg) x (1+social charges expressed as decimal) x 1000 kg/t FB =
= 0.06 US\$/kg (1 + 0.70) x 1 000 kg/t = US\$ 102/t FB

Manual sorting workers + inspectors + packagers

Amount of workers to sort, inspect and pack= 2 + 5 + 3 = 10 (from Example 2.13)
Average rate: US\$ 1.11/h (from Appendix C3)

Cost of workers =

$$= \frac{\text{No. of workers x rate (US\$/h) x h/day x (1+ social charges expressed as decimal)}}{\text{Production fillet blocks (t FB/day)}} =$$

$$= \frac{10 \text{ x US\$ } 1.11\text{/h x } 8 \text{ h/day x } 1.51}{2 \text{ t FB/day}} = \text{US\$ 67/t FB}$$

Cost of direct labour = Cost of filleters + Cost of workers
= 102+ 67 = US\$ 169/t FB

Indirect Labour (IL)

Workers (indirect labour)

Amount of workers = 2 + 2 = 4 (from Example 2.13)
Average rate: US$ 1.12/h (from Appendix C3)

Cost of indirect (or general) workers =

$$= \frac{\text{No. of workers x rate (US\$/h) x h/day x (1+ social charges expressed as decimal)}}{\text{Production fillet blocks (t FB/day)}} =$$

$$= \frac{4 \text{ x US\$ } 1.12\text{/h x } 8 \text{ h/day x } 1.70}{2 \text{ t FB/day}} = \text{US\$ } 30.5\text{/t FB}$$

Freezer attendants

Number of freezer attendants = 1 (from Example 2.13)

Average rate: US$ 1.49/h (from Appendix C3)

Cost of freezer attendant =

$$= \frac{\text{No. of worker x rate (US\$/h) x h/day x (1+social charges expressed as decimal)}}{\text{Production fillet blocks (t FB/day)}} =$$

$$= \frac{1 \text{ x US\$ } 1.49\text{/h x } 8 \text{ h/day x } 1.70}{2 \text{ t FB/day}} = \text{US\$ } 10.1\text{/t FB}$$

Cost of indirect labour = Cost of labourers + Cost of freezer attendant

= 30.5 + 10.1 = US$ 40.6/t FB

Total Cost of Labour = Cost of direct labour + Cost of indirect labour
= 169+ 40.6 = US$ 209.6/t FB

- Supervision:

Supervision of labour cost is generally estimated as a percentage of operating labour cost, a typical value being 10% (from Table 4.6).

Total Cost of Supervision = 0.10 x Cost of labour = 0.10 x US$ 209.6/t FB
= US$ 21/t FB

- Utilities:

Electricity

Energy consumption= 200 kWh/t FB (from Example 2.15)

Average rate: US\$ 0.20/kWh (from Appendix C4)

Cost of electricity = Energy consumption (kWh/t FB) x unit price (US\$/kWh)=
= 200 kWh/t FB x US\$ 0.20/kWh = US\$ 40/t FB

Water

Water consumption= 9.5 m^3/t FB (from Example 2.15)
Average rate: US\$ 1/m^3 (from Appendix C4)

Cost of water = Water consumption (m^3/t FB) x unit price (US\$/m^3) =
= 9.5 m^3/t FB x US\$ 1/m^3 = US\$ 9.5/t FB

Total Cost of Utilities = Cost of electricity + Cost of water =
= 40 + 9.5 = US\$ 49.5/t FB

- Maintenance:

Maintenance cost is generally estimated as a percentage of investment per year, a typical value being 4% for freezing plant (from Table 4.9).

Fixed Investment (I_F) = US\$ 600 000 (from Example 3.1)
Production fillet blocks = 2 t FB/ 8-hour shift
Operating days/year = 270
Annual production (Q) = 540 t FB

Fixed Investment per year = I_F / Q = US\$ 600 000/540 t FB = US\$ 1 111/tFB

Total Cost of Maintenance = 0.04 x Fixed Investment per year =
= 0.04 x US\$ 1 111/t FB = US\$ 44.4/t FB

On the other hand, the estimate allows for a seasonal pattern of availability of raw material in that the production line is operative for only 150 days per year. In many fisheries, adequate catches can only be made during certain times of the year.

Direct Costs =Raw Materials+Labour+Supervision+Utilities+Maintenance
= 761.2 + 209.6 + 21 + 49.5 + 44.4 = US\$ 1 085.7/t FB

- Investment Costs:

Depreciation

Depreciation is generally taken as straight-line depreciation over the useful life of the plant. It is assumed a service life (n) of ten years. Allocation of the depreciable cost is uniform for all years.

Fixed Investment (I_F) = US\$ 600 000 (from Example 3.1)

Because of the difficulties involved in making future estimates of salvage or scrap value, for most engineering calculations these values are usually designated as zero. Therefore, Salvage value (L) = 0

The annual depreciation cost, by Eq. (4.4) is US$ 60 000 per year.

Unit Depreciation costs = Annual depreciation cost/ Annual production (Q)=
= US$ 60 000 per year/540 t FB per year=
= US$ 111/t FB

Insurance and Taxes

Local taxes and insurance are about 2% of the fixed capital investment (from sections 4.3.1.1.2 and 4.3.1.1.3).

Taxes and insurance = 0.02 x Fixed Investment per year =
= 0.02 x US$ 1 111/t FB = US$ 22.2/t FB
Total investment costs = Depreciation + Taxes & Insurance =
= 111 + 22.2 = US$ 133.2/t FB

- Management and Administration:

This component can be estimated as a percentage of direct production costs; a typical value being 3.9% for frozen fish plant (from Table 4.14).

Management & Administration costs = 0.039 x Direct cost =
= 0.039 x US$ 1 085.7/t FB =
= US$ 42.3/t FB

- Sales and Distribution Costs:

These costs are sometimes estimated as 1% of direct costs for freezing plants (from Table 4.15).

Sales and Distribution costs = 0.01 x Direct Cost = 0.01 x US$ 1 085.7/t FB =
= US$ 11/t FB

Fixed costs = Investment + Management & Administration + Sales & Distribution =
= 133.2 + 42.3 + 11 = US$ 186.5/t FB

Unit Production Costs (excluding financing cost) = Direct Cost + Fixed Cost =
= 1085.7 + 186.5 = US$ 1 272.2/t FB

Annual Production Costs = Unit costs (US$/t FB) x Production (t FB/year)=
= US$ 1 272.2/t FB x 540 t FB/ year = US$ 686 988/year

(b) The unit production cost, by Eq. (4.22) and the coefficients from Table 4.19, are:

$$TC = 1.15\,R + 1.77\,L + 1.05\,E + 0.147\,I_F/Q$$

$$R = 693 \quad L = 209.6 \quad E = 49.5 \quad I_F/Q = 1\,111$$

Unit- of- Product cost = US$ 1 383.2/t FB

Example 4.5 Calculation of Production Costs for a Fish Canning Plant

Calculate daily production costs for the canned fish plant in Example 2.2

(a) Component by component
(b) Using coefficients given in Table 4.19

Answer: (a) The daily cost will be calculated, expressed as US$/day. Daily production is 2 670 cans of 180 g each.

- Raw Material:

Fish

Amount of raw material = 1 t tuna/day (from Example 2.5)
Price of raw material = US$ 1 000/t tuna (from Appendix C2)

Cost of Fish = Amount raw material (t tuna/day) x Price (US$/t tuna)=
= 1 t tuna/day x US$ 1 000/t tuna = US$ 1 000/day

Oil

Amount of oil = 80 kg oil/day (from Example 2.5)
Price of oil = US$ 0.5/kg oil (from Appendix C2)

Cost of Oil = Amount of oil (80 kg/day) x Price (US$/kg oil)=
= 80 kg oil/day x US$ 0.5/kg oil = US$ 40/day

Salt

Amount of salt = 12 kg/day (from Example 2.5)
Price of salt = US$ 0.5/kg salt (from Appendix C2)

Cost of Salt = Amount salt (kg salt/day) x Price (US$/kg salt)=
= 12 kg/day x US$ 0.5/kg salt = US$ 6/day

Packaging

Amount of cans = 2670 cans (from Example 2.18)
Price of can = US$ 0.12 (from Appendix C5)
Amount of cardboard boxes = 115 boxes (from Example 2.17)
Price of cardboard box = US$ 0.3 (from Appendix C5)

Cost of cans = Amount of cans (cans/day) x Price (US$/can) =
= 2 670 cans/day x US$ 0.12/can = US$ 320.4/day

Cost of cardboard boxes = Amount of boxes (boxes/day) x Price (US$/box) =
= 115 boxes/day x US$ 0.3/box = US$ 34.5/day

Cost of Packaging = Cost of cans + Cost of cardboard boxes =
= 320.4 + 34.5 = US$ 354.9/day

Cost of Raw Materials = Fish + Oil + Salt + Packaging =
= 1 000 + 40 + 6 + 354.9 = US$ 1 400.9/day

- Labour (direct and indirect):

Amount of workers = 14 (from Example 2.14)
Basic salary, including social benefits: US$ 10/day (8-hour shift) (from Appendix C3)

Cost of workers = no. of workers x rate (US$/day)
= 14 workers x US$ 10/day x worker = US$ 140/day

- Supervision:

Supervision of labour cost is generally estimated as a percentage of operating labour cost, a typical value being 10% (from Table 4.6). As one supervisor is required with a daily rate of US$ 14/day, the result is the same.

Cost of Supervision = 0.10 x Cost of Labour = 0.10 x US$ 140/day
= US$ 14/day

- Utilities:

Electricity

Energy consumption = 0.031 kWh/can (from Example 2.16)
Average rate: US$ 0.20/kWh (from Appendix C4)

Cost of electricity =
= Energy consumption (kWh/can) x unit price (US$/kWh) x production (cans/day) =
= 0.031 kWh/can x US$ 0.20/kWh x 2 670 cans/day = US$ 16.6/day

Fuel Oil

Fuel oil consumption = 0.034 kg/can (from Example 2.16)
Average rate: US$ 0.2/kg fuel oil (from Appendix C4)

Cost of fuel oil =
= Fuel oil consumption (kg/can) x unit price (US$/kg) x production (cans/day) =
= 0.034 kg/can x US$ 0.2/kg x 2 670 cans/day = US$ 18.2/day

Water

Water consumption = 8.9 l/can (from Example 2.16)
Average rate: US$ 1/1000 l (from Appendix C4)

Cost of water =
= Water consumption (l/t FB) x unit price (US$/m^3) x production (cans/day)=
= 8.9 l/can x US$ 1/1000 l x 2 670 cans/day= US$ 23.8/day

Cost of Utilities = Cost of electricity + Cost of fuel oil + Cost of water=
= 16.6 + 18.2 + 23.8 = US$ 58.6/day

- Maintenance:

Maintenance cost is generally estimated as a percentage of investment per year, a typical value being 3% for canning plant (from Table 4.9).

Fixed Investment (I_F) = US\$ 130 000 (from Example 3.2)
Production = 2 670 cans/8-hour shift
Operating days/year = 250
Annual production (Q) = 667 500 cans

Fixed Investment per day = I_F / Q = US\$ 130 000 / 250 days = US\$ 520/day

Cost of Maintenance = 0.04 x Fixed Investment per day =
= 0.04 x US\$ 520/day = US\$ 20.8/day

On the other hand, the estimate allows for a seasonal pattern of availability of raw material in that the production line is operative for only 150 days per annum. In many fisheries, adequate catches can only be made during certain times of the year.

Direct Costs = Raw Materials + Labour + Supervision + Utilities + Maintenance
= 1400.9 + 140 + 14 + 58.6 + 20.8 = US\$ 1 634.3/day

- Investment Costs:

Depreciation

Depreciation is generally taken as straight-line depreciation over the useful life of the plant. A service life (n) of ten years is assumed. Allocation of the depreciable cost is uniform for all years.

Fixed Investment (I_F) = US\$ 130 000 (from Example 3.2)
Salvage value (L) = 0

The annual depreciation cost, by Eq. (4.4) is US\$ 13 000 per year.

Unit Depreciation costs = Annual depreciation cost/Annual production (Q) =
= US\$ 13 000 per year/250 day per year = US\$ 52/day

Insurance and Taxes

Local taxes and insurance are about 4% of the fixed capital investment (from sections on property taxes and insurance, p. 115).

Taxes and insurance = 0.04 x Fixed Investment/day = 0.04 x US\$ 520/day =
= US\$ 20.8/day

Total investment costs = Depreciation + Taxes & Insurance = 52 + 20.8 =
= US\$ 72.8/day

- Management and Administration:

This component can be estimated as a percentage of labour costs; a typical value is 40% (from section 4.3.2) or as 7% of direct costs for canning plants (Table 4.14).

Management and Administration costs = 0.40 x Labour cost= 0.40 x US\$ 140/day =
= US\$ 56/day

Management and Administration costs = 0.07 x Direct cost =
= 0.07 x US\$ 1 634.3/day = US\$ 114.4/day

Average of two estimated values will be considered, therefore,

Management and Administration costs = US\$ 85.2/day

- Sales and Distribution Costs:

These costs are sometimes estimated as 1% of sales or as a percentage of direct costs (from Table 4.15).

Sales and Distribution costs = 0.01 x Sales/day= 0.01 x US\$ 2 000/day =
= US\$ 20/day

Sales and Distribution costs = 0.024 x Direct cost = 0.024 x US\$ 1 634.3/day =
= US\$ 39.2/day

A reasonable figure for sales and distribution costs is US\$ 29.6.

Fixed costs = Investment + Management and Administration + Sales and Distribution =
= 72.8 + 85.2 + 29.6= US\$ 187.6/day

Daily Production Costs (excluding financing cost) = Direct Cost + Fixed Cost =
= 1634.3 + 187.6 = US\$ 1 821.9/day

Annual Production Costs = Daily costs (US\$/day) x Operating days/year =
= US\$ 1 821.9/day x 250 days/year = US\$ 455 475/year

(b) The daily production cost, by Eq. (4.22) and the coefficients from Table 4.19, are:

$$TC = 1.3\,R + 2.22\,L + 1.05\,E + 0.237\,I_F/Q$$

$$R = 1000 \quad L = 140 \quad E = 58.6 \quad I_F/Q = 520$$

Daily costs = US\$ 1 795.57/day

5. MICRO-ECONOMIC ANALYSIS OF PRODUCTION

The production function appears in the micro-economic analysis as one of the two determining factors of the economic sustainability of the firm. A businessman aiming at a state of equilibrium in his business, trying to maximize his profits in the short run, must simultaneously consider the technological characteristics of his installations and possible ways of using them to produce. The cost of the production process must also be considered.

The first factor is formally expressed through a production function. In any given country, a specific production technique exists, based on existing installations in the various productive sectors, production processes, different forms of organization, business management and division of labour. This situation can be functionally represented by a relationship that links the value added during production, or the domestic product, to the quantities utilized from the different productive factors. These concepts constitute the aggregate production function for each sector, e.g., the aggregate function of frozen fish plants.

Knowing the production function of each sector of the fishery industry enables formulation of a response to future changes that might occur, such as: reduction of labour force, scarcity of a particular species, technological innovations. It can be utilized determine to which point it is possible to substitute one input for another. It can also be used to determine the level of operation of the plant that would constitute maximum production efficiency.

The aggregate production function can also be used as an instrument to compare the efficiency of international production and the relative price structure of products in different countries. This section looks at various properties of the production process of a firm and introduces factors that govern the selection of production technologies. The type of production process, and the properties of the production function of the company will be specifically examined.

Attention should also be paid to the role of technology and technological advances in changing the capacity of the company to produce goods and services, and the pressure on the firm to adopt new technologies.

Production is a series of activities through which inputs or resources used (raw material, labour, capital, land and managerial talent) are transformed into products (goods or services) over a specific period of time. Economists use the term production function to refer to the physical relationship between inputs utilized by the business and its products (goods and services) per unit of time (Henderson and Quandt, 1971). This relationship can be expressed symbolically as:

$$Q = f(Xa, Xb, Xc, \ldots, Xn) \qquad (5.1)$$

where Xa, Xb, Xc,....., Xn represent quantities of different types of inputs and Q the total quantity of product per period of time, for specific combinations of these inputs. There is a production function for each methodology. A company can modify the quantities of the product it generates by varying the quantities of the resources that it combines according to a productive technique, changing from one technology to another, or using both operations. It is assumed that companies use the most efficient technique such that it achieves maximum production of each alternative combination of inputs.

5.1 Production Function in the Short Run

The following parameters, which are relevant to this analysis, are defined in the micro-economic treatment of the production function:

A fixed input (FI) is defined as that input whose quantity cannot be quickly changed in the short run, in response to the desire of the company to change its production. Inputs are not fixed in the absolute sense, even in the short run. In practice, however, the cost of implementing changes in a fixed input can be prohibitive. Examples of fixed inputs are: pieces of equipment or machinery, space available for production, management personnel.

On the other hand, variable inputs (VI) are those inputs whose quantities can be easily changed in response to the desire to increase or reduce the level of production, for example, electricity, raw materials, direct labour. Sometimes variable inputs are limited in variation due to contracts (e.g., steady supply of raw material) or law (e.g., labour laws); in such cases it is possible to talk of semi-variable inputs (SVI).

The short run (SR) is the period in which the company cannot vary its fixed inputs. Nevertheless, the short run is long enough to allow variation of the variable inputs. The long run (LR) is defined as the period that is long enough to allow the variation of all inputs, none of which are fixed, not even the technology. For example, while in the short run a firm can increase its production by working extra hours, in the long run, the company can decide to build and expand its production area to install capital-intensive machines and avoid overtime.

The quantity of fixed inputs in a plant is a determining factor of the scale of operations. This scale of a plant determines in turn the maximum production limit per unit of time that the company is capable of producing in the short run. Production can vary in the short run, by reducing or increasing the use of variable inputs in relation to the quantity of fixed inputs. In the long run, production can be increased or decreased by changing the scale of production of the plant, the technology used and the use of all or any of the inputs. To analyse the short-term production function, the following concepts must be defined:

Average Product (AP) is the total production per unit of input used, and marginal product (MP) is the change in the quantity produced per unit of time, resulting from a unit change in the quantity of the variable input. The shapes of the AP and MP curves determine the shape of the corresponding production function or total product (TP).

The principle of diminishing marginal returns is related to the quantities of product that can be obtained when increasing quantities of variable inputs per unit of time are incorporated into the production process and combined with a constant quantity of fixed input. The principle establishes that a point will be reached where the resulting increases in the quantity of output will become smaller and smaller. When the average product is increasing, the marginal product is greater than the average. When the average product reaches its maximum point, it is equal to the marginal product.

Before reaching the inevitable point of decreasing marginal returns, the quantity of end-product obtained can increase at a growing rate, as shown in Figure 5.1. Above the inflection point of the production function, a greater use of the variable input induces a reduction in the marginal product. A production function and the associated AP and MP curves can be divided into three stages, as illustrated in Figure 5.1.

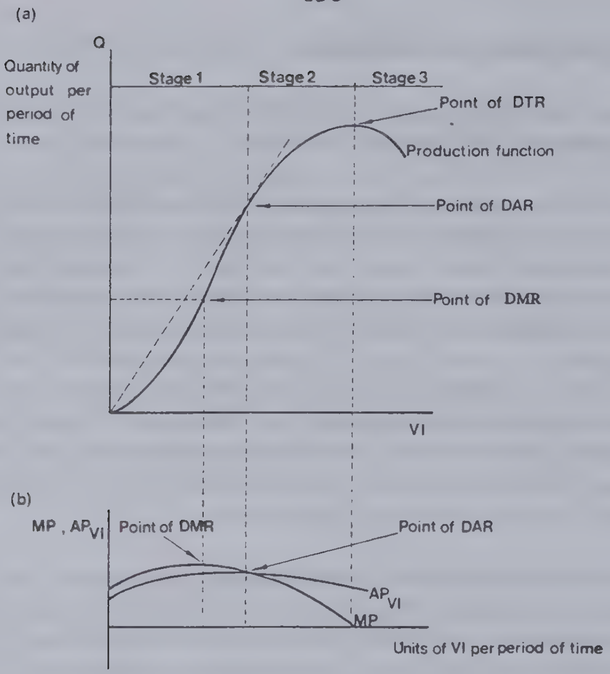


Figure 5.1 Production Function in the Short Run and the Corresponding Marginal and Average Production Functions

Stage 1 extends from zero units of variable inputs (VI) to the point where the AP_{VI} is at its maximum (DAR). Stage 2 extends from the (DAR) to the point where the quantity of product is maximum and the MP is zero (DTR). In Stage 3, from (DTR) onwards, the total product is decreasing and the MP is negative.

These stages have a special significance in analysing the efficiency with which the resources are used. The maximum of (MP) *vs* (x_{VI}) defines the point DMR, from there onwards an increase in (VI) will mean a decrease in (MP). The first stage corresponds to the range in which the AP is increasing as a result of utilizing increasing quantities of variable inputs (raw material, labour, etc.).

A rational producer would not operate in this range, because (FI) (equipment) is being underutilized. That is, the production expected from the use of more man-hours, for example, is increasing through stage 1, which indicates that the same production could be obtained with a lower quantity of fixed input. Production is also impractical at stage 3. Additional units of VI actually reduce total production.

If the efficiency of the production process is measured by the average product, which indicates the quantity of product obtained per unit of input, the previous discussion reveals that stage 2 is the best from the point of view of efficiency. In stage 1, a very small proportion of (VI) is being used when compared with the (FI). Efficiency considerations will lead to a preference to produce around the border of stages 1 and 2.

5.2 Basics of Returns to Scale

The production function of the firm has been analysed in the short run, where a proportion of the firm's resources are fixed. The concept of returns to scale occurs when the company is producing during a period long enough to allow changes in any and all of its inputs, especially those usually fixed in the short run.

Returns to scale are defined for cases where all the inputs are changed in equal proportions. In the case of a firm using X_1 units of input 1 along with X_2 units of input 2, and obtaining Q units of product, the relation can be written as:

$$X_1 + X_2 \longrightarrow Q \tag{5.2}$$

Now suppose that the quantities of inputs X_1 and X_2 are varied by an arbitrary proportion γ. Total production obviously will change. The question is in what proportion will it change? If this proportion is called π, the result is:

$$\gamma X_1 + \gamma X_2 \longrightarrow \pi Q \tag{5.3}$$

1. If the change in production is more than proportional to the change in inputs ($\pi > \gamma$), increasing returns to scale
2. If $\pi = \gamma$, constant returns to scale
3. If $\pi < \gamma$, decreasing returns to scale

For the same technology, it is usually certain that on expanding its scale of operation, the company will have:

1. A short period of increasing returns to scale

2. A long period of constant returns to scale, and,

3. A period of decreasing returns to scale

A company can increase use of its inputs to the point of maximum production; further increases of inputs can produce a stage of negative yield, where production actually decreases. However, if the concept of returns to scale is used to allow changes in the technological capacity of the firm, and its size increases, companies can be (and they certainly are) capable of applying all their tools and new technologies for expanding their scale of operations without ever reaching the point of decreasing yields.

Firms with a prolonged period of constant returns to scale are common in food and fish processing.

5.3 Basics of Cost Functions

A fundamental point in the analysis of costs is the functional relationship that exists between costs and the production for a period of time. A cost function presents different results when the plant works with different percentages of utilization. But, as previously indicated, production is a function of how resources are used.

Thus, as the production function establishes the relationship between inputs and product, once the prices of the inputs are known, the costs for a certain production can be calculated. As a result, the level and performance of the costs of a plant, as the level of production varies, are directly related to:

1. The characteristics of its own production function
2. The purchase prices of its inputs

5.3.1 Total costs and unit costs

Three concepts of total costs are important to analyse the structure of costs in the short run: total fixed costs; total variable costs; and total costs.

Total Fixed Costs (TFC) can be defined as the total sum of the costs of all the fixed inputs associated with production. As the fixed inputs for a firm cannot be changed in the short run, the TFC are constant, except when the prices of the fixed inputs change (greater taxes on property, increases in insurance premiums, etc.). Also, TFC continue to exist even when production is stopped.

Similarly, total variable costs (TVC) represent the total of all the monies that the firm spends on variable inputs used in production. As the company changes its level of production in the short run, variable costs depend on the quantity produced. The TVC is zero when production is zero in that the variable inputs are not needed at that point. Thus:

$$TC = TFC + TVC \tag{5.4}$$

This expression indicates that the total costs for a given production in the short run, is the sum of the total fixed costs and the total variable costs. The following four unit costs are relevant: average fixed cost (AFC), average variable costs (AVC), average total cost (ATC) and marginal cost (MC). Average Fixed Cost is defined by the quotient between total fixed cost and the units of production:

$$AFC = TFC/Q \tag{5.5}$$

As the total fixed cost is constant, the average fixed cost decreases as production increases; that is, the same fixed costs are distributed among more units produced. The AFC can also be calculated in the following way: the TFC is the product of the number of units of fixed inputs (FI) by the price of these inputs (P_{FI}). Substituting this in the expression 5.5:

$$AFC = TFC/Q = (P_{FI}) \times (FI)/Q = P_{FI} \times (FI/Q) \tag{5.6}$$

Since the average product of the fixed inputs has been defined as the total quantity produced (Q) divided by the number of units of fixed inputs (FI), it follows that FI/Q is the inverse of AP_{FI}.

$$AFC = P_{FI} \times (1/AP_{FI}) \tag{5.7}$$

Average variable cost is TVC divided by the corresponding number of units produced, or:

$$AVC = TVC/Q \tag{5.8}$$

Similarly, the AVC can be expressed as an inverse function of AP_{VI}:

$$AVC = TVC/Q = P_{FI} \times (FI/Q) = P_{VI} \times (1/AP_{VI}) \tag{5.9}$$

Average total cost is defined as the total costs divided by the corresponding number of units of Q:

$$ATC = TC/Q \tag{5.10}$$

However, through Equation 5.4:

$$ATC = TC/Q = (TFC + TVC)/Q = TFC/Q + TVC/Q = AFC + AVC$$

Marginal cost is the change in total costs caused by a change in the quantity of product per unit of time. As before, a distinction can be made between discrete and continuous marginal costs.

Discrete marginal cost is the change in total cost related to a 1 unit change in the quantity of the product. Continuous marginal cost is the rate of change in the total costs as production varies, and can be calculated as the first derivative of the total cost function:

$$MC = dTC/dQ \text{ (continuous marginal cost)} \tag{5.11}$$

However, given that in the short run, variation in production can only be attributed to variations in variable inputs, it is the same as measuring the variation in the discrete marginal cost by the variation observed in the total costs or in the total variable cost. Thus:

$$MC = dTVC/dQ \text{ (continuous marginal costs in the short run)} \tag{5.12}$$

Also, the MC is related to the production function. Given that changes in production in the short run are produced by increases or decreases in the variable inputs (VI), the changes in the TVC (ΔTVC) can be calculated by multiplying the price of the variable input (P_{VI}) by the change produced in the variable input (ΔVI). Thus:

$$\Delta TVC = P_{VI} \text{ x } (\Delta VI) \tag{5.13}$$

Substituting this in 5.12 and by the definition of marginal product:

$$MC = P_{VI} \text{ x } (1/MP) \tag{5.14}$$

The marginal costs are of fundamental interest as they reflect those costs over which the firm has most direct control in the short run. It indicates the magnitude of the costs that must be saved if production was reduced by one unit, or, alternatively, the additional costs that would be incurred by increasing production by one unit.

Average costs data do not reveal this very valuable information. All of these concepts can be applied to analyse the performance of a company and its different production functions. However, it is necessary to analyse in particular the total, average and marginal cost functions for the production function in the short run, with increasing and decreasing returns in function of variable inputs. The mathematical expression in this case is:

$$Q = a + b \text{ x } (VI) + c \text{ x } (VI)^2 - d \text{ x } (VI)^3 \tag{5.15}$$

where Q is the quantity of the product and (VI) the units of variable inputs, a, b, c and d are constants. The results are shown in Figure 5.2. Note the characteristic ‘S’ shape of the total cost curve.

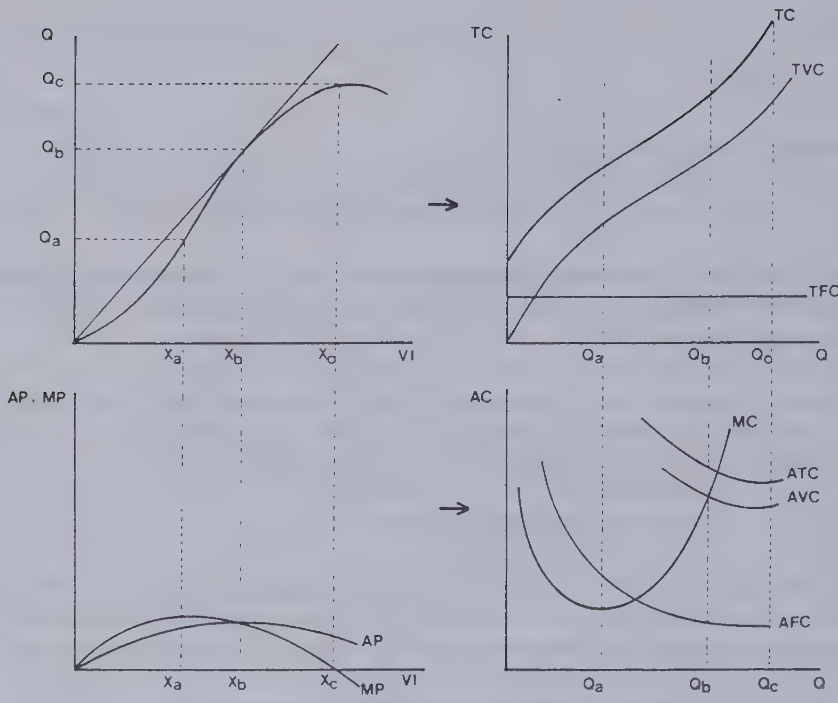

Q
Qc
Qb
Qa
Xa
Xb
Xc
VI
TC
TC
TVC
TFC
Qa
Qb
Qc
Q
AP, MP
AP
Xa
Xb
Xc
MP
VI
AC
MC
ATC
AVC
AFC
Qa
Qb
Qc
Q

Figure 5.2 Total, Average and Marginal Costs for a Plant with Increasing and Decreasing Returns to Variable Inputs

The application of these criteria to food plants (Figure 5.3) resulted in a non-linear response for semi-variable cost curves (Zugarramurdi and Parin, 1987b).

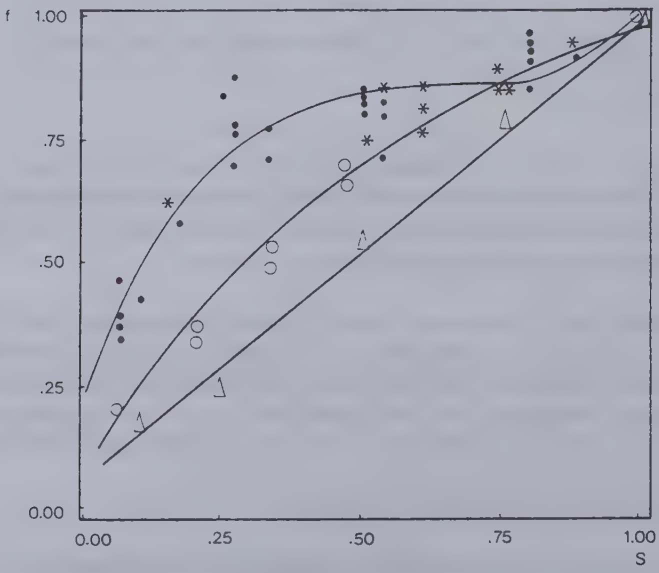


Figure 5.3 Variation of Relative TSVC (f) as a Function of Relative Plant Capacity (S) for Food Industries

Notes:

●	Long Run, extended economies in food plants: canned green beans, green peas, leafy vegetables; pumpkin and peas, canned fruit juice; canned fish.
O	Long Run, freezing plants: vegetables; strawberries.
Δ	Long Run, agricultural production: pears, lemons.
*	Short Run, canned fish.

Total semi-variable costs (TSVC) are defined as the variable costs that are not directly proportional to output like administrative services, maintenence and supervision.

5.3.2 Cost curves in the short run in the fishery industry

The cost of operating a plant at lower capacity can easily be estimated if the cost structure of a plant operating at full capacity is known. In Table 5.1, the relationship between the unit cost of production for a plant operating at a certain capacity and the costs of the same plant operating at full capacity, have been calculated for different cost structures. Values are given in the lower part of the Table 5.1 for fish plants, in accordance with the cost structures in Table 4.16 (Chapter 4).

Table 5.1
Production Costs as a Percentage of Operating Capacity

% Structure of Annual Costs at 100% of Capacity			Relationship of Relative Unit Cost with Capacity Indicated with Respect to Unit Cost at Full Capacity				
			% Operating Capacity				
Plant Type	Variable	Fixed	20	40	60	80	100
A	90	10	1.40	1.15	1.07	1.03	1.00
B	80	20	1.80	1.30	1.13	1.05	1.00
C	70	30	2.20	1.45	1.20	1.08	1.00
D	60	40	2.60	1.60	1.27	1.11	1.00
E	50	50	3.00	1.75	1.34	1.14	1.00
F	40	60	3.40	1.90	1.41	1.17	1.00
G	30	70	3.80	2.05	1.48	1.20	1.00
H	20	80	4.20	2.20	1.56	1.23	1.00
I	10	90	4.60	2.35	1.63	1.26	1.00
FISH PLANTS							
Canned Products	78.0	22.0	1.89	1.33	1.15	1.06	1.00
Salted Products	81.5	18.5	1.74	1.28	1.12	1.05	1.00
Frozen Products	82.0	18.0	1.72	1.27	1.12	1.04	1.00
Fishmeal	86.0	14.0	1.56	1.21	1.09	1.03	1.00

Fish plants clearly have a high incidence of variable costs. These are specifically raw material and intensive labour. This simplified treatment relates the variation of all variable and semi-variable costs with the utilization of the plant, although, as stated previously, semi-variable costs do not necessarily vary linearly with production in the short run. However, the low proportion of these costs on total costs allows for this estimate (Zugarramurdi, 1981a).

Values are shown in Figure 5.4 where the curves for cost structures A and I have been drawn as broken lines and those for fish plants as continuous lines.

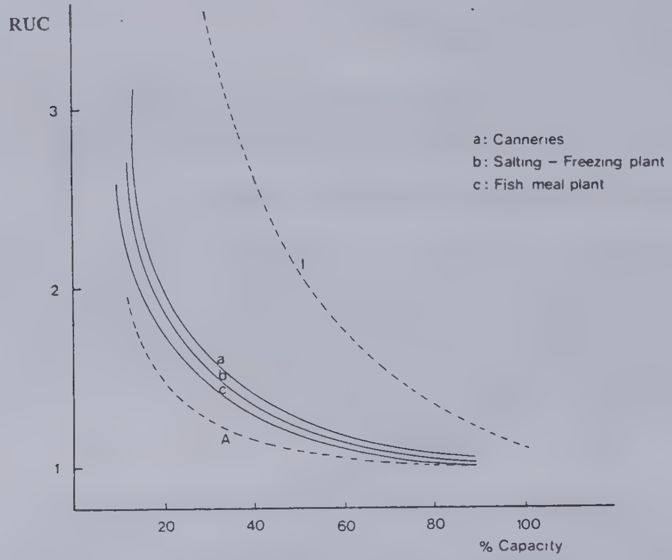


Figure 5.4 Variation of Relative Unit Cost (RUC) for Different Levels of Production in Fish Plants (A and I cost structure defined in Table 5.1)

5.4 Average Cost Curve in the Long Run

As fixed inputs no longer exist in the long run, the distinction between fixed and variable inputs disappears and there are no TFC or TVC curves. It is only necessary to look at the shape of the average cost curve in the LR. Suppose the technological restrictions allow a firm to choose between the construction of three plants of different sizes: small, medium and large. The sections of three short run average cost curves that identify the optimum plant size for a given level of production are shown as a continuous line in Figure 5.5.

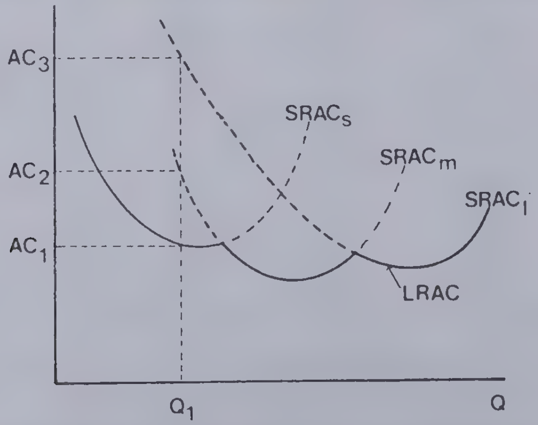


Figure 5.5 Average Total Cost Curve (ATC) in the Long Run for Three Possible Plant Sizes

The continuous line in Figure 5.5 is called the average cost curve in the long run (LRAC) and shows the minimal unit cost for any production when all the inputs are variable, and any size plant can be constructed. The dotted lines of the short run average cost curve

(SRAC) curves always refer to greater costs at each production than what can be obtained with plants of other sizes.

The final selection will depend strongly on the market demand and the demand tendencies of the consumer, which generally favour large sized plants when planning for the future. On the other hand, the medium sized plant could be more attractive because of its smaller capital investment requirements. Usually, the firm will have more than three sizes from which to choose. When the number of options is large, the LRAC curve is tangent to the SRAC curves (see Figure 5.6).

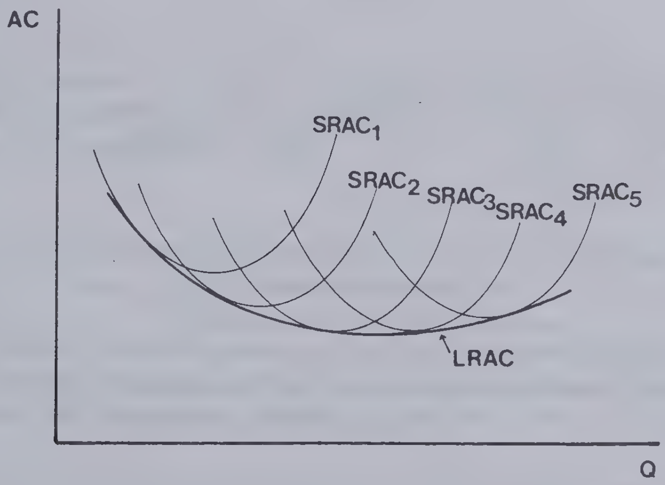


Figure 5.6 Average Cost Curve in the Long Run for Plants of Any Size

The most efficient of all possible plants is that whose SRAC curve is tangent to the LRAC curve at the lowest point. Figure 5.6 gives the optimum size plant on the $SRAC_4$ curve.

5.4.1 Cost curves in the long run for actual plants

In practice, there are different shapes for LRAC and the reasons for that and how they relate to plant capacity should be analysed. The first possibility to be analysed is that of industries where the AC decrease steadily with Q. It can be seen that at high volumes of production there is a large sub-division of the productive process and a specialization in the use of inputs such as raw material, labour and supervision.

A direct consequence of this is an increase in efficiency and a reduction of costs. Also, large plants can, as a result of their volume of business, secure large discounts on the prices of raw materials and therefore offer their customers better conditions of sale, thus penetrating the market.

There are also advantages at company organization level, since administrative and managerial personnel are shared by different production units. A large firm, whether through vertical integration or by diversification, can deal with changes in the market such as sharp increases in prices, scarcity of raw material or technological innovation. These economies of scale are extremely important and cause the LRAC curve to decrease for the large production range. Examples are automobile, aluminum, steel, paper, aviation and farm machinery plants. In the food industries, some vegetable canneries, juice plants and fish canneries are cases in point (Figure 5.7).

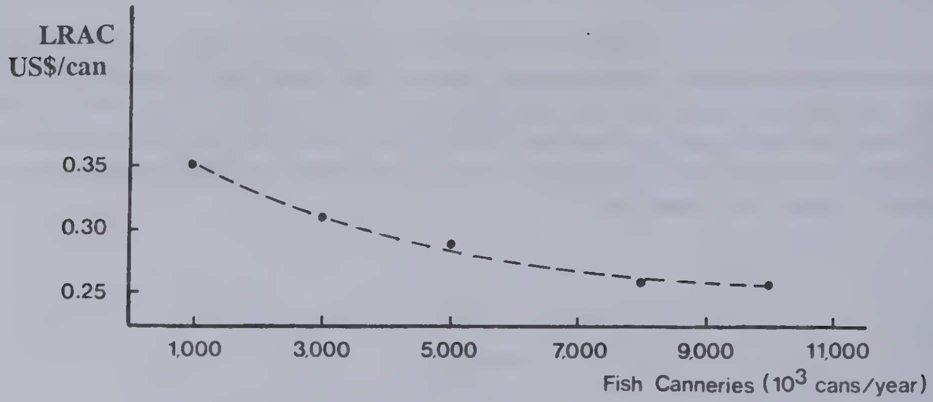


Figure 5.7 Average Cost Curves in the Long Run, with Optimum Plant Scale Case of Extended Economies

In some industries increases in size tend to create problems. This is because dis-economies of scale are created by growing difficulties at the managerial level, which consume more time and money, and produce problems concerning the inputs and their supply.

Figure 5.8 shows an LRAC curve for these businesses when dis-economies of scale occur at low production levels; for example, agriculture, printing, bakeries, electronics, instruments, and non-alcoholic drink bottling. Examples in the food sector where small-scale firms have cost advantages over large-scale enterprises, include frozen vegetables processing plants.

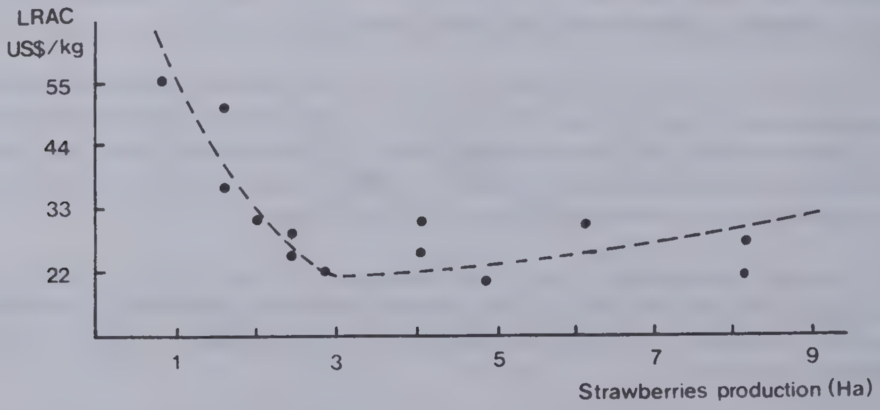


Figure 5.8 Average Cost Curves in the Long Run, with Optimum Plant Scale. Case of Early Dis-economies.

Figure 5.9 shows a LRAC curve with a flat bottom, which implies constant returns to scale over a wide range of capacities. Examples are: home appliances, furniture, textiles, chemical industries, and meat, fruit and vegetable packaging.

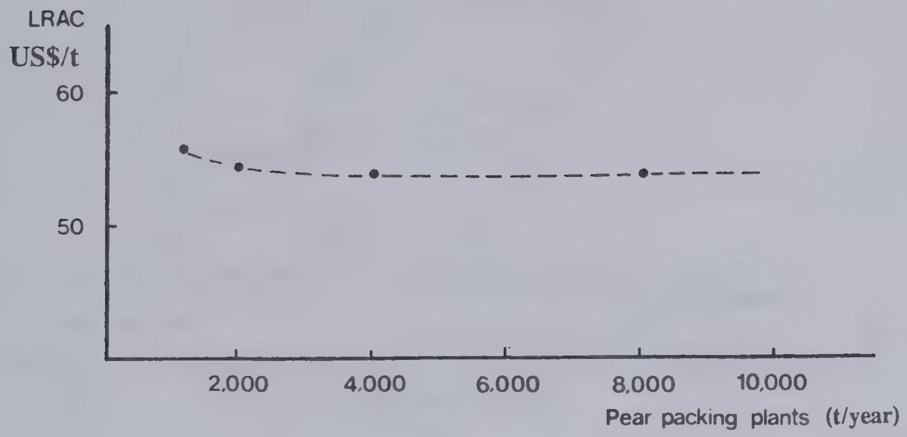


Figure 5.9 Average Costs Curve in the Long Run, with Optimum Plant Scale. Case of Constant Average Costs.

Example 5.1 Production Costs in the Short and Long Run for Industrial and Artisanal Fishmeal Plants

Calculate and compare the production costs in the short and long run for fishmeal plants: artisanal plants in Africa and large-scale plants in Europe.

A small plant is operating in Africa with a capacity of only 100 kg of raw material/day (with a 20% yield). This plant uses simple technology in order to adapt to the characteristics of the area in which it is located. Cooking is done indoors and drying is by solar energy (Mlay and Mkwizu, 1982). On the other hand, large scale plants are operating in developed European countries, working efficiently with large capacities, using technologies that include plants for concentrating stickwater (Atlas, 1975).

Answer:

In general, when production costs are analysed, the concept of economy of scale would seem to indicate that the plant with the greatest level of production is the most suitable. However, some economic studies (Cerbini and Zugarramurdi, 1981b) show that in developing countries the level of productivity that is the norm in more industrialized countries could be assured even when the entire market is being supplied by a single factory.

These circumstances indicate the existence of a special technical problem in developing countries, which is the application of processes that permit improvement in productivity for smaller scale operations.

The application of these procedures, which are considered classical in developed countries, leads to excessive operating costs and lower production efficiency in countries with small markets.

Figure 5.10 shows the costs in the short and long run for both economies.

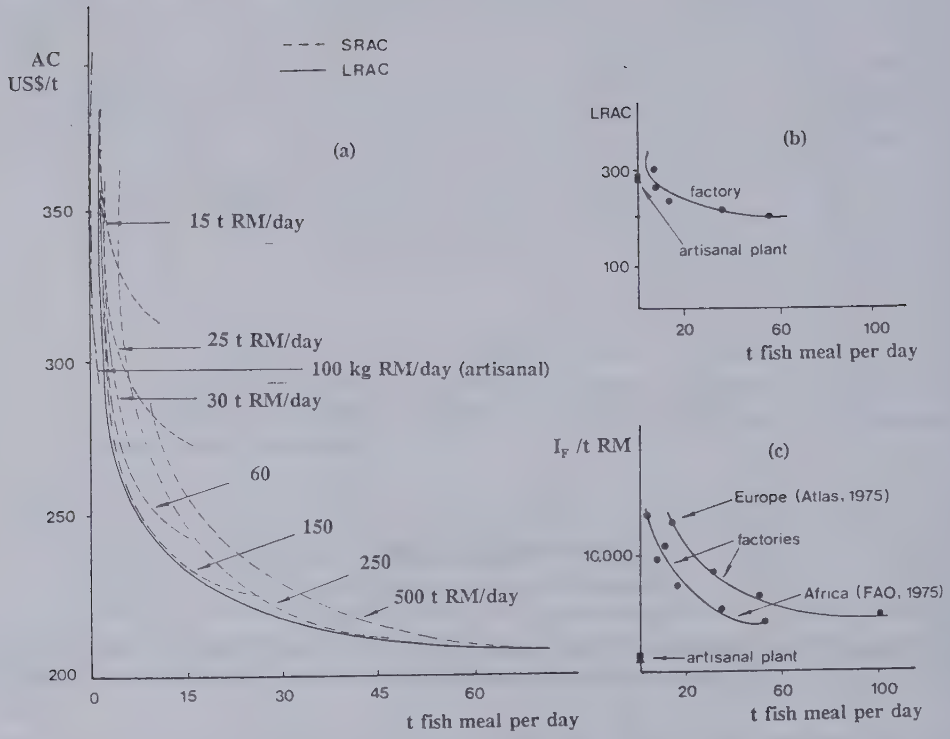


Figure 5.10 (a) Production Costs in the Short and Long Run for Fishmeal Plants;
(b) Production Costs in the Long Run for Fishmeal Plants;
(c) Relationship Between Investment and Raw Material Processing Capacity (US$/t RM) versus Production Capacity (t).

It is clear that use of appropriate technology in each country or region results in lower production costs and efficient use of local inputs. Operating costs behave in a manner consistent with the concept of economy of scale.

Artisanal plants can be installed with the technology best suited to a particular country in accordance with the availability of inputs. The result is considerably lower production costs. However, depending on the type of product and process, there could be technical and economic reasons that render these alternatives non-viable when production capacity should be increased.

For example, labour costs increase considerably when there are large volumes to be processed, as is the case with natural drying. It is not possible to control insect infestation efficiently, and raw material is lost, with a consequent increase in total cost of production. When all these factors are quantified, the actual cost curve for artisanal and industrial fish meal production would assume a shape like that drawn by a broken line in Figure 5.11.

In this situation, both types of production - artisanal and industrial - could even coexist, as is the case in Tanzania with the production of fishmeal from *Haplochromis spp.* in Lake Victoria in the 1970s and 1980s (the industrial fishmeal production ceased when the *Haplochromis* fisheries collapsed following the introduction of Nile perch in Lake Victoria.

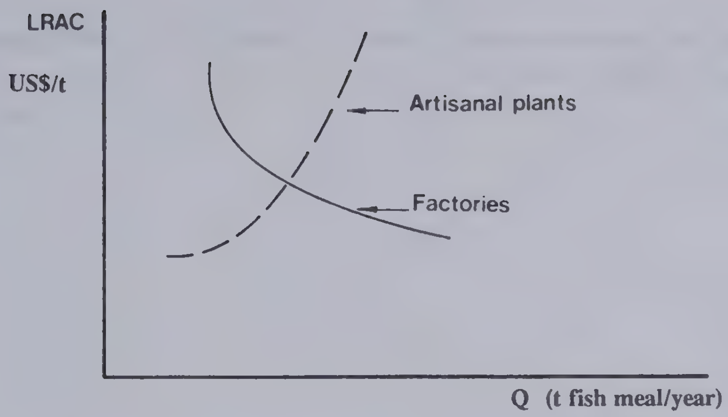


Figure 5.11 Average Cost Curves in the Long Run for Artisanal and Industrial Fishmeal Plants

Example 5.2 Analysis of Average Cost Curves in the Long Run for Small Fishing Vessels in West Africa

Analyse the economies of scale for small fishing vessels of the west coast of Africa: (a) Ghana; (b) Côte d'Ivoire; and (c) Senegal according to the data provided by Frielink, 1987.

(a) Ghana. The sardine fisheries (*Sardinella* spp.)

Two types of fishing vessels are used for the exploitation of sardines in this region;some are less than 12 m long and others between 12 and 22 m. Thirty-two vessels, representing approximately 10% of the total fleet registered in 1983, were studied. They were categorized according to three different size groups: 0 m-9.9 m, 10.0 m-18.3 m and 18.4 m-30.5 m. The groups contained 7, 14 and 11 vessels respectively. Analyse the costs of fishing given in Table 5.2 for each group. Variable costs represent approximately 75% of total costs; a result that holds true for many other fisheries. Fuel represents about 30% of total cost.

Answer: It can be seen that the largest vessels (C) are the least profitable. Gross income, which is 13.5% greater for the (C) vessels when compared with the (B) vessels, does not compensate for the 19.6% increase in production costs.

Table 5.2
Catch, Income, Costs and Profitability of Fishing Vessels in Ghana

Vessels	Small (A)	Medium (B)	Large (C)
Catch (t/year)	178	208	236
Gross Income (US$/year)	33 820	39 520	44 840
Investment (US$)	47 150	58 720	65 675
Total Costs (US$/year)	29 455	34 742	41 546
Average Costs (US$/year)	165	167	176
Rate of Return (%)	5.67	4.77	1.6

The average cost values have been plotted in Figure 5.12. Note the occurrence of early dis-economies of scale.

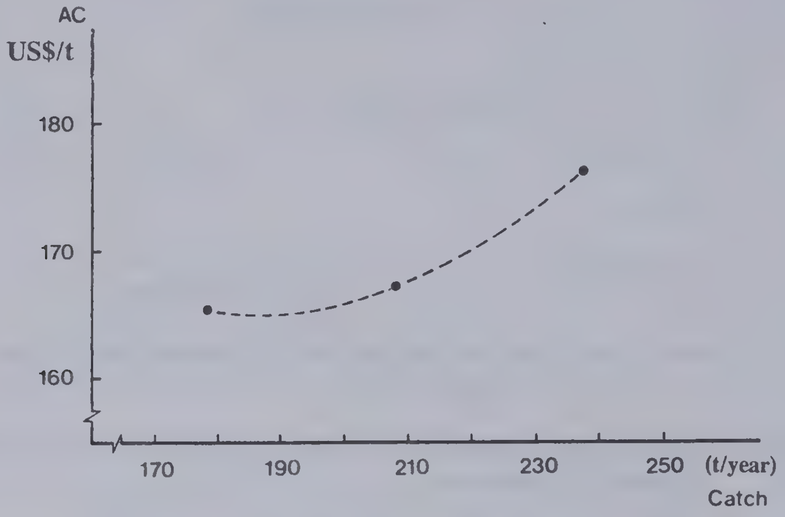


Figure 5.12 Average Cost Curves in the Long Run for Fishing Vessels in Ghana

(b) Côte d'Ivoire. The sardine fishery in Abidjan

Sixteen vessels between 18.4 and 28.8 m long operated in the Côte d'Ivoire in 1983. They were wooden motorized boats built in Abidjan, with no refrigeration system. For the purposes of this study, they were divided into two categories: small boats, about 240 hp; and large boats 450 hp.

As there were large differences in the performance of the individual boats in each group, average values were selected, instead of using typical boats. The total number of trips in 1983 was 110 and 122, respectively, with total catch of 1 425 and 1 723 t. The costs and profits of this fishery are shown in Table 5.3.

Table 5.3
Catch, Income, Costs and Profitability of Vessels in Côte d'Ivoire

	Small Vessels	Large Vessels
Capture (t/year)	1 425	1 723
Gross Income (US$/year)	422 716	513 853
Average Costs (US$/t)	229.5	256.2
Rate of Return (%)	15.8	7.4

The difference between sizes (A) and (B) is not great in terms of profitability, but the medium-size vessel is probably a better investment as it is supposed that it will have more possibilities and a wider range of action (Frielink, 1987).

Answer: Figure 5.13 shows that average costs present early dis-economies, and demonstrates that profit for large vessels is 35% lower than for small vessels.

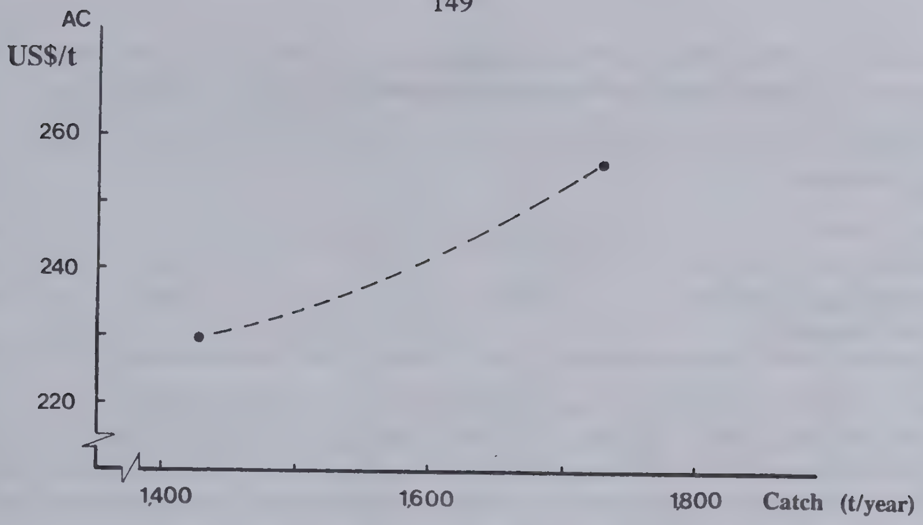


Figure 5.13 Average Cost Curves in the Long Run for Fishing Vessels in Côte d'Ivoire

As in other fisheries, variable costs represent about three-quarters of the total. There are no great differences in the cost structure of either class of vessel, except for fuel and lubricants, and interests. In large vessels, fuel costs are relatively high and, due to a larger investment, must support substantially higher interest payments.

Historically, the costs of large vessels have been almost double those of smaller vessels. Production and income per fisherman are 10% lower for large vessels, indicating a decrease in productivity as motor power - common in this activity - increases. Also, the aggregate value per fishing vessel is higher for the large vessels, due mainly to the high interest paid. The rate of return is acceptable for small fishing vessels and more than the bank rate. This is also true for large fishing vessels, although 7.4% is too low for the risk involved in the activity (Frielink, 1987).

(c) Senegal. The small pelagic fishery in Dakar

The purse seiners of the Dakar fleet are composed of different types and sizes of fishing vessels. The sizes vary from 22 to 256 t gross weight, with motors ranging from 110 to 600 hp. The old fishing vessels are made from wood and the newer ones of fibreglass. Table 5.4 shows the composition of the fleet, with the vessels grouped into four classes.

Table 5.4
Characteristics of the Purse Seiners Fleet in Dakar (Senegal)

Class	Construction Material	Catch 1983 (t)	Catch per Trip (t)	No. of Trips Per Year	Members of crew	Investment (US$)
C1	Fibreglass	392	3	140	10	157 480
C2	Fibreglass	1 370	5.5	249	16	289 000
C3	Wood	1 159	6.1	190	20	525 000
C4	Wood/Steel	2 200	11.0	200	24	630 000

Table 5.5 shows the costs and income of the four types of boats for 1983.

Table 5.5
Catch, Costs and Profitability of Fishing Vessels in Senegal

Type of Vessel	C1	C2	C3	C4
Catch (t/year)	392	1 370	1 159	2 200
Gross Income (US$/year)	55 559	194 173	164 268	311 811
Average Costs (US$/t)	169.4	117.0	188.6	141.9
Rate of Return (%)	-	8.4	-	-

Answer: The cost structure is somewhat different from the other fisheries. Total variable costs are less than 75% of the total. The main reason is that the fishing effort is unusually low. The fishing vessels must operate 250-280 days/year. Also, due to the short trips, fuel costs as a percentage of the total are 11-18%, instead of the 25-30% observed in other fisheries. The salaries are relatively high as they are partly fixed. An analysis of Table 5.5 shows that only the C2 vessels operated profitably in 1983. The other vessels, e.g., C3 reported sizable losses.

The main reason for the high profitability of the C2 vessels in relation to the other type of vessels seems to be the number of trips made. C4 vessels suffered losses in spite of their high catches, probably due to their high depreciation costs. Figure 5.14 shows the average costs for the four types of vessels. Observe that the medium fibreglass boats are most suitable.

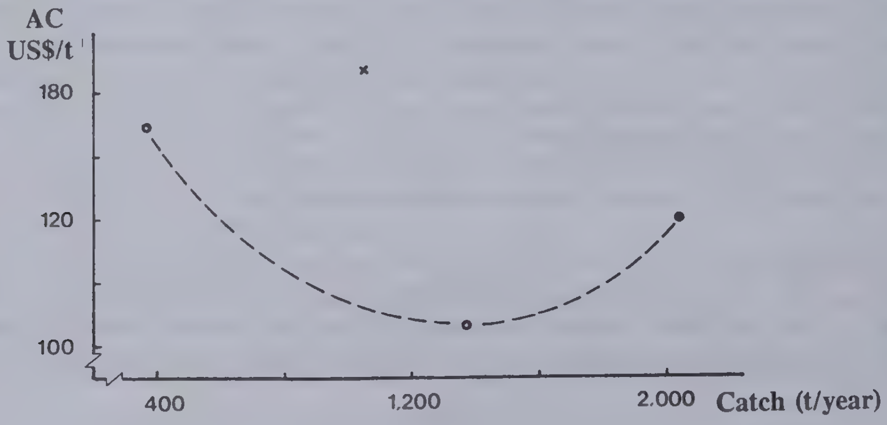


Figure 5.14 Average Cost Curves in the Long Run for Senegalese Vessels

Example 5.3 Analysis of Economies of Scale in the Production of Fishmeal and Fish Oil in Oman (Arnesen and Scharfe, 1986)

A significant resource of mesopelagic fish with a high productivity rate has been found in the Gulf of Oman. Each trawler can catch an average of 60 t/day of fish, 250 days/year, for possible use as raw material in a reduction plant. These figures are conservative, as trawlers can land above average catches when fish is abundant. Analyse and choose the most suitable daily raw material capacity between two plants whose nominal capacities are 250 and 500 t/day.

Answer: A study was made of reduction plants with capacities of 250 and 500 t raw material per day. For this study, once the production process was selected, investment and production costs were calculated for different capacities in the short and long run, as indicated in Table 5.6.

Table 5.6
Income and Costs for Fishmeal Plants

Capacity	250 t/day			500 t/day			
Raw Material (t/24h)	100	175	250	200	250	350	500
Sales of Fishmeal and Fish Oil (US$ '000)	3 025	5 294	7 562	6 050	7 562	10 587	15 125
Variable Costs: plant & boats (US$ '000)	799	1 224	1 647	1 405	1 688	2 252	3 100
Fixed Costs: plant & boats (US$ '000)	3 663	3 663	3 663	4 855	4 855	4 855	4 855
Average Cost (US$/t)	850	532	399	596	498	387	303

A plant with a 500 t/day capacity is much more flexible than one with a 250 t/day capacity, but the costs of a 250 t plant are not very different from a 500 t/day plant. Building an oversized plant is a safety measure, so that when trawlers supply up to 90 t/day during periods of high catches, it can be processed during the course of the day. A plant that produces at reduced capacity can produce fishmeal with a lower fat and higher protein content.

With two 8-hour shifts, the plant can consume up to 240 t of fish, production being interrupted one day/week in order to allow for a proper cleaning and maintenance programme. It is, however, impossible that a plant with a nominal capacity of 250 t/day can absorb this quantity for an average of 250 days/year, not even with highly trained workers. From experience, it has been determined that up to 70% of the nominal capacity can be used over the 250 days/year. This represents an average production of 175 t of fish/day. The reasons for reducing actual capacity are:

- The actual capacity of the plant and the quality of fishmeal are strongly dependant on the freshness of raw material. If raw material is too old there is an increase of losses and a decrease in fishmeal quality. If fish is too fresh (e.g., in *rigor mortis*) there are working problems to grind and transport the raw material and the quality of the resulting fishmeal may not be acceptable for the customer.

- There are large oscillations in daily catches, around 60 t/day per trawler. Catches below average cannot be compensated by catches above average at a later date.

- A well-run factory usually stops production one day/week for cleaning and maintenance. A stop in production may occur in the best plant. The stops will reduce the nominal daily production average.

- An average production of 175 t/day of raw material is equivalent to 58.3 t/day per trawler, a value close to the design capacity (with a profit of US$ 400 000/ year). However, if the plant is to be served by 4 trawlers, the catch per trawler must be limited to 43.75 t/day, and 250 days of production will give a loss of US$ 530 000.

In Figure 5.15, the results for the unitary costs have been plotted.

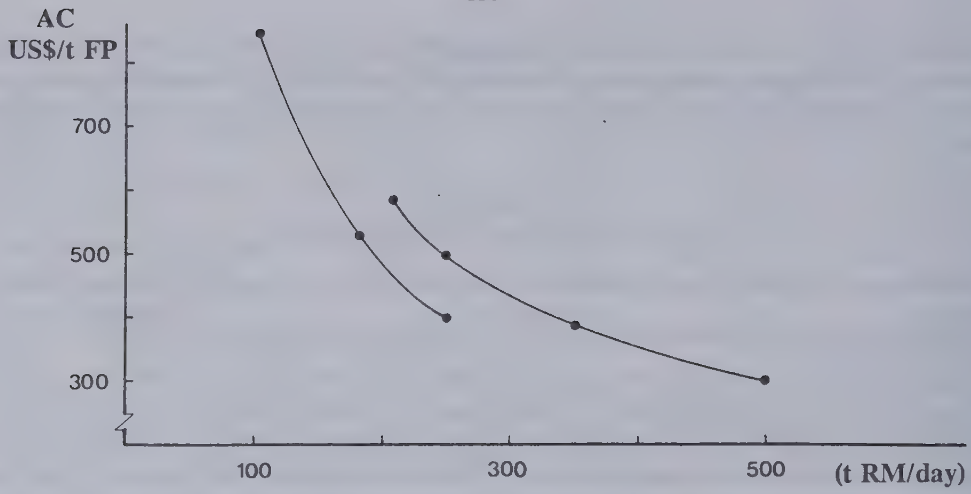


Figure 5.15 Average Costs in the Long Run for Fishmeal Plants

If a minimum catch of 60 000 t of fish is anticipated, the average will be 60 t per boat, when four trawlers are used over 250 fishing days/year. This catch must be processed by a plant with a nominal capacity greater than 250 t/day. For these reasons, the 500 t/day plant has been chosen (Arnesen and Scharfe, 1986).

5.5 Micro-economics Applied to a Whole Fishery

The application of micro-economics to fish catching and processing was discussed above in a way that could be defined as the individual owner's or company's point of view. In particular, in the case of fish catching no biological conditions were imposed on calculations, e.g., level of availability of resources, although they were in practice affecting the estimates. However, as fish is a renewable resource depending on defined physical and biological conditions, they should be taken into account, in order to find out how a fishery as a whole (not just a given type of fish processing plant or fishing boat) can be operated in a sustainable way.

Micro-economics applied to fisheries is now a well developed branch of modern fish biology, where the interaction of biological knowledge and micro-economics has led to the development of mathematical models regarding the economics and sustainability of a fishery as a whole. This approach allows for the definition of useful limits and conditions in exploitation of a given single or multi-species fish resource and establishment of general fishery policies (to be enforced by Governments and/or self-enforced by fishermen and the fishery industry. It is for the single fisherman or company, to adjust his own micro-economic analysis to the general micro-economic analysis of the resource for his exploit (and the whole exploitation) to be sustainable. In practice, this is one of the main problems of today's fisheries.

The production function has been defined as the relationship between the quantity of inputs used and the resulting quantity of product. In terms of a fishery, the production function expresses the relationship between the fishing effort applied and the fish caught. A fishery is considered here to be a stock of a species exploited by a group of fishermen, boats or fishing units. In practice, conditions are as complex as the fisheries are varied. The production function in a fishery depends on the reproductive biology of the stock of fish. Most theoretical treatments of fisheries economics use the analysis originally defined by

Schaefer (1954), where the growth of a stock of fish is assumed to be a function of volume, expressed in units of weight.

The biomass of an unexploited fishery resource will grow at different rates depending on its size, and will increase towards a maximum point which, once attained, will remain constant. This population size is known as the population size in the virgin state (Anderson, 1974). The physical and chemical parameters influencing the fish population size and the rate at which the resource reaches its maximum point, include salinity, temperature, prevailing currents, feeding habits of other species, rate of photosynthesis, quantity of radiated solar energy and rate at which mineral elements are replaced.

If these parameters are assumed to be constant, the three population components that will determine the growth of the resource are: recruitment (the biomass of fish that enters the population that can be caught in a period), individual growth (the biomass of each individual fish in the population for that period) and natural mortality (weight of biomass of fish of the population, lost due to natural death and predators during that period); the period is normally one year.

In the Schaefer analysis, it is assumed that the increase in the biomass of a fishery is a function of the population. It can be shown as a bell-shaped curve, as shown in Figure 5.16(a). The horizontal axis measures the size of the population, and the vertical axis the growth per period; both are given in terms of weight.

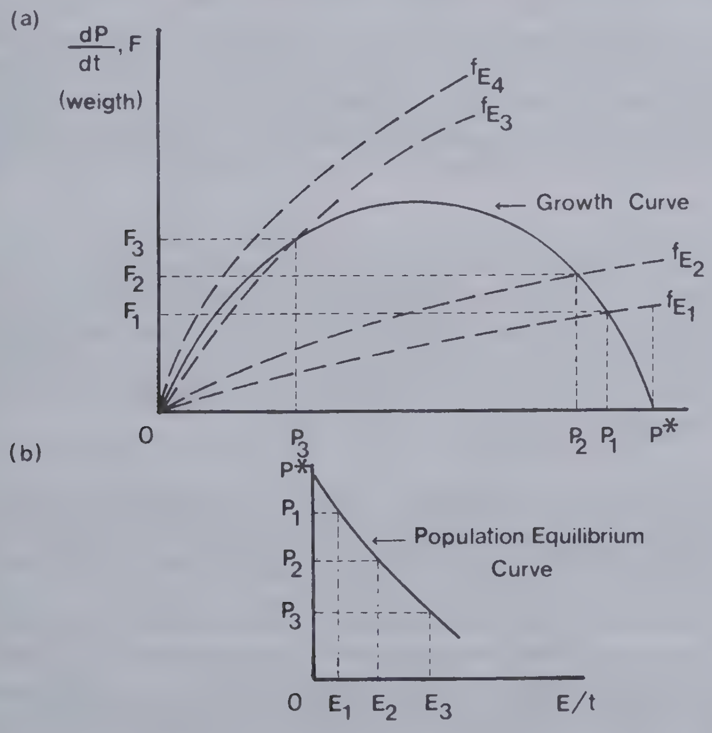


Figure 5.16 (a) Growth Curve;
(b) Population Equilibrium Curve as a Function of Fishing Effort

For example, when the population has a value of P_3, the net increase in size or growth will be V_3. For stocks of small size, the net effect of recruitment and individual growth is greater than natural mortality. The natural growth is positive and increases with the size of the stock. A point will eventually be reached where recruitment and individual growth will equal natural mortality, and the growth of the stock will cease. This struggle between different forces can vary with different species, but in general the growth curve maintains its bell-shape. In some cases, the right side of the curve can asymptotically draw nearer to the horizontal axis, in a more or less pronounced manner.

According to Figure 5.16, P* is the size of stock in which recruitment and natural growth are compensated for by natural mortality. Therefore, the population will not grow above this size. This point will be the natural population equilibrium. For any smaller population, growth will continue until it reaches size P*.

When man begins to exploit a fishery, he becomes a predator who disturbs the population equilibrium. A new equilibrium point will thus be reached, where the net increase in weight due to natural factors, will equal the net reduction due to the fishing mortality. At any point in time, the catch or fishing mortality will be a function of the size of the stock and the quantity of fishing effort that is applied to the fishery. For any population size, the greater the fishing effort, the larger the catch; and for any degree of effort, the larger the population the larger the catch. Mortality due to fishing can be shown on a graph as a function of the fishing effort if the population remains constant, or as a function of the population if the effort remains constant.

Given that the catch varies with levels of effort, the equilibrium size of the population will differ for each level of effort (Figure 5.16.b). This is important as fishing effort is a variable defined by man and should be controlled by him. The catch is a function of the size of the stock and degree of effort, but as the size of the stock in the equilibrium is a function of effort, the yield of fish in the equilibrium (V) is a function of effort only. In Figure 5.16, four dotted curves have been drawn showing the fishing mortality by weight (catch) that will occur during a period for different population sizes, each exploited by a different fishing effort.

The catch obtained from a level of effort and its corresponding population equilibrium is called Sustainable or Sustained Yield. It is sustainable because the size of the population will not be affected by fishing, since catch is balanced by the natural increase of the stock. Therefore, the same level of effort will supply the same level of catch in the following period. The series of points which represent catches from sustainable yield for each level of effort, is called the Sustainable Yield Curve.

For the hypothetical fishery in Figure 5.16, Figure 5.17.a would be obtained. The vertical axis measures catch in weight and the horizontal axis measures the effort, as would occur for a typical production function in the short run, with effort as a variable input.

The concepts of average and marginal sustainable yield, whose curves are shown in Figure 5.17 b, are also important. These concepts are also comparable with the average and marginal products. Average sustainable yield, the sustainable yield per unit of fishing effort, Y/E, decreases continuously until it reaches the value zero, at the same point at which total yield is zero.

Marginal sustainable yield, the change in sustainable yield due to a change in fishing effort, or ($\Delta Y/\Delta E$), is positive, but declines and reaches zero at the level where the Maximum Sustainable Yield (MSY) is obtained. Then it becomes negative. This implies that additional levels of effort over the point of MSY will actually reduce catch.

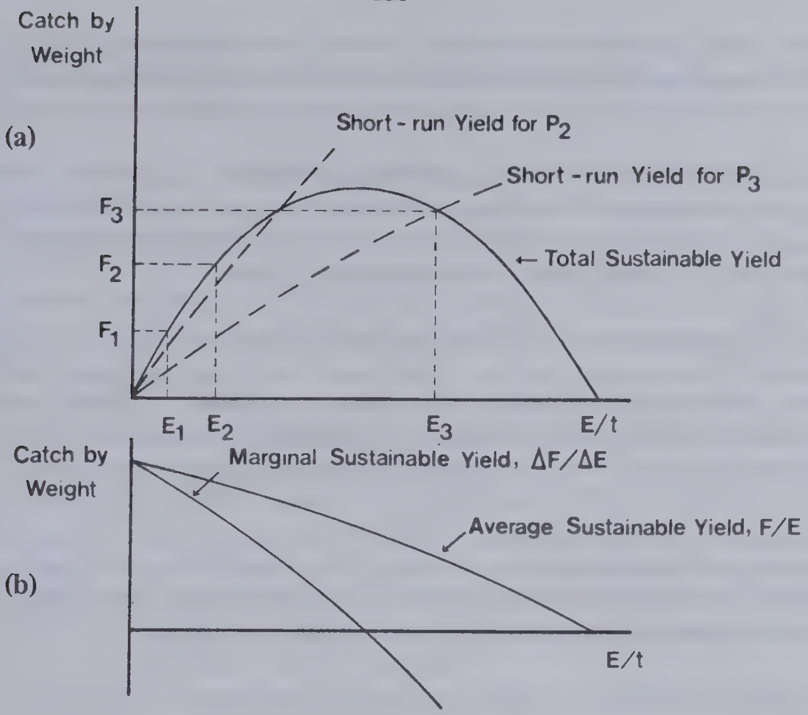


Figure 5.17 Total, Marginal and Average Sustainable Yield Curves

The sustainable yield curve can be considered the production function of a fishery in the long run; i.e., it will show the quantity of the resource that can be "produced" with a sustained base at different levels of fishing effort. Changes in fishing effort will produce a change in the equilibrium size of the population, but time will pass before the new equilibrium can be reached.

In cases where this delay is substantial, the yield curves for specific population sizes can be used as production functions in the short run, such as those shown by dotted lines in Figure 5.17 a (they are inverse to the catch and population curves shown in Figure 5.16 a. A different curve is necessary for each population size. Of the two curves shown, the higher one corresponds to the larger population (P_2, and P_3 are the same as in Figure 5.16).

5.5.1 Mathematical models for evaluation of the fish resources

In order to evaluate the state of a fishery resource, determine the volume of catch that can be obtained and estimate the effects of different fishing alternatives, the effects that fishing has on the fishery resource must be quantified, mathematically showing possible population changes that might occur as a result of the different exploitation alternatives (Csirke, 1988).

The general concept used to develop the models of population dynamics that are used to evaluate fishery resources and recommend management measures can be simplified by Russell's formula:

$$F_2 = F_1 + (R + G) - (M + C) \qquad (5.16)$$

where F_1 and F_2 represent the biomass of the population at the beginning and at the end of a specific period respectively; R, the quantity of recruits or of new individuals that have become part of the population; G, the increase in weight caused by the growth of the existing fish in the population; M, the quantity of fish that died from natural causes; and C, the quantity of fish caught or killed by fishing during that same period of time.

According to this model, the population is maintained in equilibrium when the natural increase of the population (R + G) remains equal to its decrease (M + C) as a result of natural causes and fishing. In other words, the population tends to increase or decrease according to whether the increases or decreases are greater.

Of all these parameters, the only one that can be controlled by man is catch (C), through which he can change the size of the population during successive periods (F_2, F_3, ...F_n). One of the preoccupations of each fishing community is the determination of the maximum level of catch (C) and the size of the population (S_i) that, once kept in equilibrium (that is, where M+C = G+R), will allow the maximum catch to be obtained.

The methods that are generally applied to estimate the size of a population and the possible relationship between the rate of natural increase and the intensity and conditions for exploitation (for example, rate of exploitation, age at first capture, etc.) can be grouped into analytical or structural methods and synthetic or global methods.

Analytical or structural methods are used to study population size and dynamics by examining its main components and the changes that they experience. On the other hand, synthetic methods, best shown by global production models, are those that treat the population as a closed entity where no notice is taken of changes that occur internally. Only the relationship between the stimulus, usually represented by the intensity (fishing effort), and the total catch and catch per unit effort (response) obtained, are analysed.

The following analytical methods will be examined:

- Yield by Recruitment Model

In the application of the yield by recruitment model (Ricker, 1975; Gulland, 1969; Csirke, 1980; Pauly, 1980 or 1982), information, data and samples collected from the commercial fishery, as well as from exploratory fishing where available, are used to estimate the parameters of the population. Of all the parameters, the only ones that can be voluntarily controlled by man are fishing mortality, which is assumed to be proportional to the fishing effort (number of boats, fishermen, etc.) and the size or age at which the fish can be caught (which can be modified by changing the size of the nets, avoiding spawning areas, etc.).

If these parameters are known, a rather complex equation proposed by Beverton and Holt (1957) or some modified version proposed by other authors, can be used to estimate the average catch that each recruitment can yield, for a certain combination of fishing mortality values and age at first catch. If the recruitment is known, it will also be possible to estimate the total potential catch of the entire year class and of the population.

- Virtual Population Analysis (VPA)

The method of analysing virtual population allows the history of an entire year class to be reconstructed (which when added to other year classes allows the history of the entire population to be reconstructed) from the catches and estimated natural mortality of that year-class during the time that it was exploited and the fishing mortality and abundance during the last year or fishing season. In this way, with a retrospective analysis of the catch of each year class over time, an estimate can be made of the number of individual fish that were present in the population in the past.

To apply this method, the total catch and the natural mortality in each year, for each group of a certain age needs to be known, in addition to the fishing mortality or abundance for the last fishing season. Then a series of equations (presented and discussed in detail in the works of Gulland, 1971; Pope, 1972; and Cadima, 1978) are applied to estimate the size of each year class and the population that existed in the past. Other methods are used when the time series values for catch and effort are not available (Garcia *et al.*, 1989).

Analysis is made of the global method of production based on the law of population growth in the natural state and which follows a sigmoid shaped curve. Schaefer (1954) proposed a method for estimating the potential catch of a fish population, relating surplus production or sustainable yield to a measure of the population abundance or the fishing mortality.

This model rejects the assumption that under equilibrium conditions, the abundance or catch per unit effort (U_t) decreases in a linear form with increases in fishing effort (E). This relationship can be represented by the equation:

$$U_t = U_{00} - b \times E_t \tag{5.17}$$

where: U_t is the abundance; E_t is the fishing effort at a specific time; U_{00} is the index of the catch capacity or population size in the virgin state, and b is a constant.

Using this equation, and defining abundance as proportional to catch per unit effort (U = V/E), the following relationship between capture (V) and fishing effort (E), can be derived:

$$Y_t = U_{00} \times E_t - b \times E_t^2 \tag{5.18}$$

which describes a parabola, where each point on the curve corresponds to a level of catch or equilibrium yield (V) according to the specific level of fishing effort (E_t). The highest point of the parabola is known as Maximum Sustainable Yield.

The simplicity of the fundamental theories and the fact that only data on catch and fishing effort are required (easily acquired statistical data which are also used for other purposes and by other users) resulted in production models and data collection on catch and effort, becoming the standard method for analysing and evaluating most fisheries. In many cases, this leads to erroneous conclusions, due to the lack of complementary information.

Pella and Tomlinson (1969) and Fox (1970) have proposed modified versions of this model in order to adapt it to specific applications and improve adjustments in particular cases. Csirke and Caddy (1983) proposed a modified version which allows this type of model to be applied to fisheries for which only data on catch or abundance indices, and estimates of total mortality are considered. This is particularly useful in cases where adequate data do not exist.

The conclusions drawn from an analysis of the characteristics of the dynamics of the fish populations must be expressed in terms which can be used by those who are not biologists, and have the responsibility of planning and managing fisheries development. Thus, models have been formulated such that the results can be expressed by relating equilibrium catches to the different values of fishing mortality which, for practical reasons, are normally shown by their corresponding value for fishing effort (for example, number of boats, trips, fishing hours, number of fishermen) (Csirke, 1985).

The advantage of expressing the results in terms of catch and fishing effort is obvious, since these are precisely the units with which those persons responsible for fishery management must deal continuously. The exact shape of the curves that relate catch to effort and catch per unit effort (apparent abundance) to effort can change according to the particular model used and the type of fishery being analysed. However, these two curves usually have the same shape as those in Figure 5.17.

The general conclusion that can be drawn, with respect to the relationship between catch and fishing effort, is that, taking zero as a starting point, small increases in effort will be followed by an almost proportional increase in catch. However, the rate of increase in catch begins to decline at high effort values (catch per unit effort also decreases), reaches zero, and then becomes negative on the right side of the curve, entering what is known as a level of over-exploitation.

The point where the increase in catch with respect to the increase in effort is zero corresponds to the level of Catch or Maximum Sustainable Yield (MSY), which would be the optimal level of exploitation if the aim of the fishery is to obtain the greatest sustainable catch possible.

Economic sustainability and social consideration are now receiving more attention and implications of these aspects are shown in Figure 5.18. Figure 5.18(a) gives the relationship between gross value of the catch (X-axis) and total costs of exploitation (Y-axis).

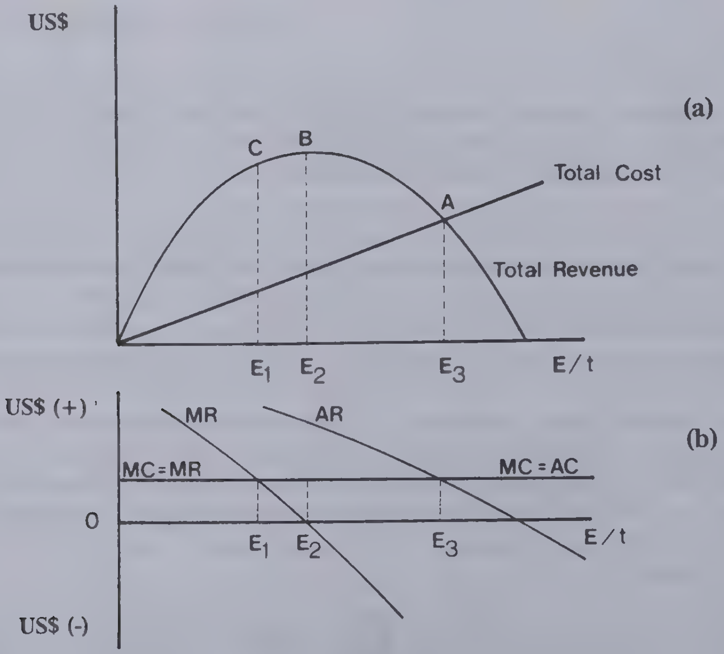


Figure 5.18 Income and Total, Marginal and Average Cost Curves

The gross value of the catch is greatest at point B. At point A, the gross value of the catch is equal to operating costs at which profitability is zero. The maximum economic profitability (maximum net economic yield) is point C. From the economic point of view, this is the optimum catch level, but if other considerations are used (for example, maximizing total catch) the entry of new fishing units can be authorized, up to point B. Also, in the absence of a good policy for fisheries management, an equilibrium point can be reached where the value of the catch is equal to total costs (point A). In extreme cases the fishery can also stabilize at a more reduced level of catch (point D) where the value of the catch only serves to cover current costs (fuel costs, salaries, insurance, maintenance of vessels and fishing gear, etc.) and due to a lack of amortization and reinvestment, the fishery runs the risk of entering a process of gradual degradation.

Figure 5.18(b) shows other economic indices. The slope of the continuous line shows the marginal economic yield or net aggregate value added to the total catch with the entry of each new fishing unit (and corresponding increase in total fishing costs). The marginal yield shows the aggregate value for the entire fishery by the addition of one fishing unit (e.g., the entry of a new boat). The marginal yield starts off high, but begins to decline rapidly as fishing intensity increases. At a certain point, the marginal yield will be equal to the costs of the new fishing unit (point C); that is, the level at which net economic yield is highest.

This is probably the point at which fishing should be maintained if net economic yield is to be maximized, as any increase in the fishing effort will cost more than the corresponding increase in total value produced by fishing, and would obviously be unprofitable if the fishery was considered as a whole. However, the criterion used to determine whether a boat should be built or a new one allowed to enter, is normally the potential catch of this boat and not the increase in total catch for the entire fleet. The catch by a new fishing unit can in fact be less, since the activities of a new boat could reduce the abundance of the population that is being exploited, and thus reduce the catch of the other boats. This is a very important aspect to consider when an increase in fishing effort and the development of a particular fishery are proposed (Csirke, 1985).

Just as it is possible to incorporate economic criteria into models of population dynamics, social criteria that tend to maximize the number of job positions, number of fishing units, etc., can also be incorporated. Models of population dynamics provide useful information on the limits for the development of a fishery and the consequences for the fish population and for man himself, if the number of fishing units are increased or reduced.

In an unregulated fishery, the level of fishing effort for equilibrium in the fishery will be E_3, where total income equals total costs. It is also the point at which average revenue per unit effort is equal to average costs per unit effort. At this point, total revenue for the fishery to the left of E_3 is greater than total costs. Therefore, each vessel will realize profits, i.e., average income per unit of fishing effort is greater than the average costs per unit of fishing effort. This situation will not only prompt the existing vessels to increase their effort, but will also motivate new units to enter the fishery. The opposite case is shown on the right of E_3. Given that fishing effort tends to increase below E_3 and decrease above this point, the fishing effort equilibrium level in an open access fishery will stabilize at this point.

This can also be called a bio-economic equilibrium point. The level of fishing effort will not change unless prices and costs vary. Fish population will also remain constant. The adequate use of a resource requires maximization of its net yield. This guarantees that production is maximized. In Figure 5.18, this situation is shown at point E_1, where the annual profit of the fishery as a whole (difference between income and costs) is at its maximum. Any increase in effort above E_1 will reduce annual profits, as costs will increase more than income.

Income measures what the population is prepared to pay for the fish, and costs represent the value of the opportunity costs of those inputs required to produce the effort used to catch the fish. Therefore, when the marginal cost of effort is greater than the marginal income, the company is losing, as it is obtaining additional fish at a cost higher than its worth to the consumers. In other words, when fishing effort increases, inputs are being diverted from producing other goods that are more valuable to the company.

On the other hand, if the effort was reduced, profit would also decrease implying that income is decreasing faster than costs. Therefore, although the resources could be used in other types of production, the resulting goods would have a value lower than that of the fish that could have been caught with E_1. This is called Maximum Economic Yield (MEY) of the fishery. What is important at the MEY point, is not the maximization of the profits of the fishery as a whole, but that the company's inputs not be used to exploit the fishery, unless they cannot be used more advantageously elsewhere.

The majority of small-scale fishery resources can be exploited by anyone who wishes to do so. This natural open access to the fishery tends to lead to biological overfishing (beyond MSY) and to economic overfishing (beyond MEY), to the point where the total costs of fishing equal the total income obtained from fishing. While the MEY can, in rare cases, be found to the right of the MSY, the maximum economic profit for the country, resulting from fishery activity, is generally found to the left of the MSY. A point on the curve that relates yield to the size of the resource and the quantity of the fishing effort that is found on the right of the MSY, denotes additional fishing effort and a smaller population size; a point on the left of the MEY denotes less fishing effort, and a greater population size.

Similarly, the theory of sustained development can be applied to the case of a fishery or a natural, renewable resource. This new concept of development will succeed if the biological, economic, political and cultural aspects are simultaneously accounted for. It can be defined as a collection of goals whose change with time must be positive. Some of the goals are increase of real income *per caput*, improvement of the sanitary and nutritional level of the population, expansion and extension of education, increase of resources, (natural or man-made), an equitable distribution of income, and an increase of fundamental freedom. The fulfilment of these goals is subject to the condition that the stock of natural capital must not decrease with time. A comprehensive definition of natural capital involves all the natural resources, from petroleum to the quality of the soil and continental waters, to the stock of fish in the oceans, and to the capacity of the planet to recycle and absorb carbon dioxide. If this theory is applied to the treatment of a fishery, the following equation is derived:

$$(dR/dX) \times (1/\pi) = P - C(X) \qquad (5.19)$$

where:

R = $[P - C(X)] \times Y(t)$, sustained revenue or profit of the activity
X = growth of stock
π = discount rate
P = price of natural resource

C = unitary cost of capture
Y(t) = capture

Its deduction and modifications when the price of the resource changes, are given in the References (Pearce *et al.*, 1990). There are hardly any data on growth rates of the resources, which hinders the analysis of MEY. In order to study the income and costs of a fishery, three types of data are needed: (1) an estimate of the sustainable yield curve, (2) an estimate of the average costs of effort and (3) an estimate of the price of the resource.

From the Schaefer model, the sustainable yield curve can be mathematically expressed as:

$$Y = c \times E - d \times E^2 \tag{5.20}$$

where:

Y = capture
E = fishing effort
c and d constants

Using standard mathematical techniques, it can be shown that the MSY will be equal to $c^2/4d$ and will be obtained when the fishing effort is equal to $c/2d$.

To apply the model's equation to a fishery, it will be necessary to obtain estimates of c and d. From the equation for sustainable yield, the average sustainable yield per unit of fishing effort can be expressed as:

$$Y/E = c - d \times E \tag{5.21}$$

Therefore, using data on catch and total effort over a period of years, estimates for c and d can be obtained by using the minimum squares technique.

Example 5.4 Lobster Fishery in the Northern USA (1950-66)

This type of analysis was applied to the lobster fishery in the northern USA in order to obtain a rudimentary overview of the operation of open access fisheries and to recommend regulation policies (Bell and Fullenbaum, 1973; Fullenbaum and Bell, 1974). The following equation was estimated using data acquired for catch and effort between 1950 and 1966.

$$Y/E = -48.4 - 0.000024 \times E + 2.126 \times {}^\circ F \tag{5.22}$$

According to this estimate, an increase of 100 000 traps would reduce annual catch per trap by 2.4 lb, and a temperature increase of 1°F would increase catch by 2.126 lb. If 46°F, which was the average temperature for 1966 and which is close to the average temperature for the past 65 years, were used, the result would be an MSY of 25 459 million pounds, that would have been caught by 1 030 000 traps. This means:

$$Y = 49.4 \times E - 0.000024 \times E^2 \tag{5.23}$$

If the operating costs of a vessel are known, as well as the average number of traps that each carries, total costs (TC) can be expressed as a function of effort,in the following way:

$$TC = 21.43 \times E \tag{5.24}$$

and if this were divided by total yield, the average costs would be:

$$AC = \frac{21.43 \times E}{49.4 \times E - 0.000024 \times E^2} \tag{5.25}$$

Solving the quadratic equation (5.23) to obtain $E = f(y)$ and substituting it in equations (5.24) or (5.25), equations are obtained that are an exclusive function of Y. Similarly, marginal costs can be estimated in terms of yield, as the derivative of the total cost equation. If the results are analysed, it is observed that as the number of traps increases, total yield decreases, but average cost per pound continues to increase, as more money is being spent to obtain a lower yield.

To determine the equilibrium point, an examination must be made of the following demand curve by applying standard econometric techniques, with data on prices for landed lobsters, consumer income, population of the USA, consumer price indices, total consumption, total imports and total production of lobsters in the USA compared with production in the north.

$$\text{Price} = 0.9393 - 0.005705 \times Y \tag{5.26}$$

On analysing the demand Equation (5.26), it was observed that if the lobster catch increased by 1 million lb, the price dropped by less than 0.5 cents/lb. The equilibrium point is found by making the demand equation equal to the average cost curve. At the point where they intersect, a price of US$ 0.7952 and a total mass caught of 25.24 million lb, were obtained. To obtain this yield 933 000 traps must be used. The actual figures for 1966 were: US$ 0.762, 25.6 million lb and 947 113 traps.

The MEY occurs at the intersection of the marginal costs curve and the demand curve. The equilibrium price was US$ 0.833, with a total yield of 18.57 million lb, using 490 000 traps. The average costs per pound, operating at this production level, was US$ 0.571. Total income at this point, which is equal to the difference between sale price and cost multiplied by total yield, was US$ 4 865 340.

Another conclusion could be the following: if the production of the fishery had to be reduced from 25.24 to 18.57 million lb and the number of traps from 933 000 to 490 000, this would lead to a decrease in the average costs per pound, from US$ 0.7952 to US$ 0.571, with a combined decrease in total costs of US$ 9 467 378. This reduction implies, when considered along with the concept of opportunity costs, that there are goods with this same value that can be produced in other parts of the economy.

At the same time, the reduction in total yield caused an increase in price and a reduction in the consumption of lobster, resulting in a loss of US$ 4 602 038. Subtracting this amount from the increase in production of goods in other areas, it is found that moving to the MEY point allowed the company to obtain a net profit of US$ 4 865 340, which is the same as the profit made by the fishery when it was operating at MEY (Anderson, 1974).

Fishing companies must have a sufficient understanding of the micro-economic management of the fishery as a whole, since their development and functioning over time depends on it. It is also essential that this knowledge be available to fishermen's associations and fishery industry in general, since it is a common problem.

Another example of the application of these concepts was the Cyprus fishery (Hannesson, 1988), where effort was measured in units of fishing days. Optimum effort was found to be 105 fishing days/mi^2 for some fishing areas, and 175 fishing days for others. These levels are far below the actual levels of fleet operation, 67% of the average levels between 1983 and 1984 and 58% of the level in 1984. Similarly, the economic benefits have been calculated assuming optimum effort yields a total catch of 1 360 t. This can be compared with actual catch in recent years in Cyprus, which ranges from 1 038 t in 1980 to 1 952 t in 1984.

Several policies that can be used to reduce the level of fishing effort to optimum levels, have been analysed using these results. One of these methods is to gradually reduce the level of effort, after having first stopped the increase in effort. Obviously, alternative means of employment for those persons leaving the fishery will have to be considered.

This reduction in fishing effort can be achieved by dividing the total catch into individual quotas, limiting fishing licences, imposing a resource tax on fishing, excluding some occasional fishermen, and assigning specific zones for fishing permits. It has been proposed that fishing licences or quotas be granted to fishermen who are actively engaged in fishing when the regulation is introduced, and then quotas or licences be bought back, as needed, until the optimum fishing effort is reached.

The micro-economics of a fishery as a whole, and the various possibilities for its regulation, have been extensively studied (Csirke, 1985; Doubleday, 1976; Gulland, 1974; Gulland and Boerema, 1973).

6. ANALYSIS AND SELECTION OF ALTERNATIVES

The aim of this chapter is to enable the selection of alternatives for which capital might be required during a period, such as engineering projects or general business dealings. It is essential to consider the effect time has on capital, as capital must always produce some yield. If time-value relationships are not adequately accounted for, the results of the economic studies will be inaccurate and could lead to incorrect decisions. Appendix B gives a concise review of financial equations, necessary to calculate interest and time value of money.

6.1 Selection of Alternatives

Despite the fact that experience, intuition and judgement are still the dominating factors in high-level decision-making and in the majority of decisions at the operational level, significant progress has been made in the use of quantitative techniques that help the decision-making process through the use of economic models. Direct testing of alternative operational procedures is usually costly and, in many cases, impossible. However, the decision models and the simulation process provide a suitable medium where the evaluator can obtain information from the operations under his control without disturbing the operations themselves. As a result, the simulation process is essentially one of indirect experimentation through which alternative courses of action are tested before being implemented.

The economic models are formulated to provide the analyst with a quantitative base for studying the operations under his control. The method consists of four steps:

- Define the problem
- Formulate the model
- Run the model
- Make the decision

The methodology applied in each case depends on its nature, and on a clear definition of the objective being pursued. Among the different methodologies available are:

- Selection of alternatives through analysis of the present-worth and equivalence point
- Optimization techniques
- Methods for calculating project profitability
- Break-even analysis

Analysis of the present-worth and equivalence point will be discussed in this chapter, where a brief introduction to optimization techniques has also been included. Methods to calculate project profitability and break-even analysis will be discussed in the next chapter.

6.1.1 Analysis of present-worth

The decision-making criteria must incorporate an index, equivalence measure or base for comparison that summarizes significant differences between different proposals. The relationships and equations developed here are the necessary elements that allow comparisons to be made between two or more alternatives that have the same or different useful life. Data required include initial investment, uniform or irregular operating costs, salvage value and useful life.

The alternatives that can be obtained are the result of considering different sums of money in relation to different times, within the useful life of the alternatives. To enable the most appropriate selection to be made, these alternatives must be reduced to a common time base, that is, the comparison must be made at the same point on the time axis. The most common bases for comparison are:

- Present-worth: comparing equivalent quantities calculated at the present time.
- Annual uniform costs: the comparison is made between annual uniform equivalent quantities at year end (time base: one year)
- Capitalized costs: comparison is made on the premise that funds will be available to replace the equipment, once its useful life is ended (time base: infinite).

Example 6.1 Selection of Alternatives with Equal Useful Life
Manual vs Mechanical Heading, Gutting and Labelling in Small Fish Canning Plants

Analyse the following proposal. Substitute machinery for labour in the heading, gutting and labelling operations in small fish canning plants in tropical countries. Production capacity is 10 000 cans of 125 g of sardines each, every 8 hours. Table 6.1 shows the investments and operating costs for each alternative. Ten % per year is adopted as the time value of the money. Working with these conditions, determine the most satisfactory decision that can be made from an economic point of view. Express the result as present-worth and annual uniform cost.

Table 6.1
Investment and Operating Costs for Alternatives A and B

	Alternative A	Alternative B
Investment (US$)	172 930	154 006
Labour costs (US$/year)	42 408	71 714
Maintenance costs (US$/year)	7 965	7 022
Consumption of electricity (US$/year)	1 262	942
Insurance (US$/year)	1 596	1 398
Useful life (years)	10	10

Answer:

$$\text{Present-worth} = P_{A10} = 172\ 930 + (42\ 408 + 7\ 965 + 1\ 262 + 1\ 596) \times F_{AP}^{10\%,\ 10} = $$
$$= 172\ 930 + 53\ 231 \times 6.15 = \text{US\$}\ 500\ 300$$

$$\text{Present-worth} = P_{B10} = 154\ 006 + 81\ 076 \times 6.15 = \text{US\$}\ 652\ 623$$

where $F_{AP}^{10\%,\ 10}$ is the value factor for an interest rate (i) equal to 10% for a 10 year (N) period (see Appendix B Table B.2).

$$\text{Annual Uniform Costs} = A_A = P_{A10} \times F_{AP}^{10\%,\ 10} = 500\ 300 \times 0.163 = \text{US\$}\ 81\ 450$$

$$\text{Annual Uniform Costs} = A_B = P_{B10} \times F_{AP}^{10\%,\ 10} = 652\ 623 \times 0.163 = \text{US\$}\ 106\ 377$$

where $F_{AP}^{10\%,\,10}$ is the recovery factor for i = 0.10 (10%) and n = 10 ($F_{AP}^{10\%,\,10} =$ $= 1/F_{AP}^{10\%,\,10}$) (see Appendix B, Table B.2).

The economic effect of the substitution of equipment by labour depends on the costs of the additional labour in relation to capital expenditure. From the preceding data, alternative B for intensive labour results in higher costs (30%). However, it could be considered that the social benefits arising from the increased employment will amply compensate for this economic disadvantage and tip the balance towards the adoption of labour intensive technology (Edwards, 1981).

Example 6.2 Selection of Alternatives with Different Useful Life.
Natural and Mechanical Fish Drying

Analyse the natural or mechanical drying of small freshwater fish from an East African country (Waterman, 1977). Annual production is 53 t, with a yield of 32.5%, working at full capacity 12 hours/day, 250 days/year. The product is sold in bulk and not packaged. Mechanical drying is achieved in a small-scale drying chamber, indirectly heated by Diesel oil, with forced-air circulation and a 12-hour drying cycle. Its useful life is estimated as approximately 10 years. Consumption of fuel, electricity and labour will have to be taken into consideration.

Sun-drying is accomplished on frames built from wood and wire mesh, the useful life of which is one year. Just over 5 kg of fish can be spread out on 1 m^2 of frame, and the drying cycle lasts 5 days. Double labour is used in this procedure. Table 6.2 gives all the values for investment and costs. Express the results as present value and annual uniform cost.

Table 6.2
Investment and Costs for Mechanical and Natural Drying

	Alternative C	Alternative D
Investment (US$)	9 000	720
Labour costs (US$/year)	375	750
Maintenance expenses (US$/year)	1 200	360
Electricity consumption (US$/year)	4 440	-
Useful life (years)	10	1

Answer:

$$P_{C10} = 9\ 000 + (1\ 200 + 4\ 440+375) \times F_{AP}^{10\%,\,10} \quad = \text{US\$ } 45\ 992$$

$$P_{D1} = 720 + (750+360) \times F_{AP}^{10\%,\,1} \quad = \text{US\$ } 1\ 729$$

where $F_{AP}^{10\%,\,1}$ is the present value factor for i = 0.10 (10%) and a period of one year (n = 1).

It would not be equitable to compare the present-worth of the cost of 10 years service for alternative C with the present-worth of the costs of one year's service for Alternative D. Application of the following equation allows for conversion of the present-worth of an alternative with a useful life of (n) to its equivalent present-worth for any other useful life (k):

$$P_K = P_N \text{ x } \frac{F_{PA}^{10\%,n}}{F_{PA}^{10\%,k}} \qquad (6.1)$$

where $F_{PA}^{10\%,n}$ is the capital-recovery factor over n periods
and $F_{PA}^{10\%,k}$ is the capital-recovery factor over k periods.

Equation (6.1) was developed by Jelen (1970). In this case, the present-worth of the costs of alternative D for a period of 10 years is:

$$P_{D10} = 1\ 729 \text{ x } \frac{1.1}{0.163} = \text{US\$ } 11\ 668$$

Expressed in annual terms, (see P to A equation in Table B.2, Appendix B) the values are:

A_C = US\$ 7 492 and A_D = US\$ 1 901

The economic comparison shows that natural drying has still a favourable annual difference of US\$ 5 591 when compared with mechanical drying, even when calculations are adjusted for difference in useful life. Moreover, in practice, each comparison contains intangible elements. In this case, to obtain good production of naturally dried products in tropical climates, the following must be considered: temperature and humidity of the air, lean or fatty raw material, duration of rainy season, market characteristics and conditions where fish is marketed, etc. If monetary values could be assigned to all of these elements, they could be included in the quantitative analysis and thus substantially modify the result.

Nevertheless, with regard to fish drying, the economic difference in favour of natural drying continues to be very great in many practical situations, and this is basically why more technologically advanced drying methods have not been adopted in developing countries, despite the effort of developing agencies (national and international). It is worth mentioning that natural fish drying is still used in Japan and some Scandinavian countries.

6.1.2 Point of equivalence

In a situation where costs can be expressed as a function of a common decision variable (number of units of production, duration of operation, etc.) these alternatives can be analytically or graphically evaluated by applying the following criteria: Point of equivalence: is the value of the common decision variable for which the costs of both alternatives are equal.

For instance it is feasible to apply this decision model to the following options:

1. With the prospect of a new frozen fishery product, it is necessary to assess the volume of production at which the costs of expanding the existing refrigeration capacity will be equivalent to the costs of using nearby refrigeration services; viz., whether refrigeration services should be rented or constructed;

2. When the request of a client makes it necessary to acquire a new machine, the

monthly operation time must be known in order to determine whether it would be more profitable to buy the machine instead of renting it.

Example 6.3 Determination of Equivalence Point
Local vs Imported Mackerel for the Canning Fishery Industry

Analyse the costs of production for canned fish using local or imported raw material. Determine the price (expressed in US$/can) of the national raw material, which will be equivalent to the price paid for the imported raw material. The example corresponds to the situation which occurred in Argentina in 1986, when imports of H&G mackerel from Ecuador increased, as an alternative to canning. It should also be stated that there is a coastal fleet in Mar del Plata which engages seasonally in the capture of this species.

Data common to both alternatives:

- Average bimonthly production: 1 million cans of 380 g each plant
- Packaging, packing, oil, and salt, are bought in cash at the beginning of the season
- Payment of direct labour: fortnightly
- Payment of indirect labour: monthly
- Sales begin after the 60th day
- Average interest rate: 1% per month

Fresh mackerel (whole); local

- Mackerel harvesting period in Argentina: 15 November-15 January
- Payment for raw material - after 15 days (0.5 month)
- Average raw material yield: 38%

H&G frozen mackerel; imported

- Shipment arrival date: 15 November
- FOB value: US$ 390/t
- Payment for raw material: after 90 days
- Importation cost (freight, insurance, etc.): US$ 210/t (cash)
- Average raw material yield: 67%

Answer:

Costs of equivalent production will be calculated (present-worth, with zero time at 15 November) for each of the possible raw materials. This will depend on factors such as: yield of raw material, value of import dollar, value of monthly interest rate. Those factors that differ in each alternative will be considered, since there are certain inputs (quantity of cans, consumption of vegetable oil as filling, income from sales, costs of direct labour, costs of indirect labour) that are equal for the same level of production (in quantity and duration).

Two production alternatives are considered using a simplified model. Such production plans are limited to a two month period. In a detailed analysis, however, an annual production programme would have to be examined, together with the sales forecast. Moreover, the opportunity costs of the working capital would have to be considered; that is, financial costs of packaging, raw material, labour and 30 days of finished product would have to be included (Parin and Zugarramurdi, 1986b).

To achieve the desired production level using a national supply of mackerel, raw material must be purchased once a month. For imported mackerel, one purchase is made and the mackerel is kept frozen. Cold storage should be paid every 30 days, at a rate of US$ 1/t/day.

Local mackerel:

- Raw material

$$\frac{1\,000\,000 \text{ cans} \times 0.38 \text{ kg/can} \times (1-0.2)}{0.38} = 800\,000 \text{ kg fish/2 months}$$

20 000 boxes are therefore needed every two months (1 box = 40 kg).

Costs of Raw Material (Ci) : Prices between US$ 10 and US$ 20/box will be considered.

$$\begin{aligned}
TCi &= 10\,000 \text{ boxes} \times Ci \times (1 + 0.01)^{-0.5} + 10\,000 \text{ boxes} \times Ci \times (1 + 0.01)^{-1.5} \\
TCi &= 10\,000 \text{ boxes} \times Ci \times [(1 + 0.01)^{-0.5} + (1 + 0.01)^{-1.5}] \\
TCi &= 10\,000 \text{ boxes} \times Ci \times (0.99504 + 0.98518) \\
TCi &= 19\,822.5 \text{ boxes} \times Ci \qquad (6.2)
\end{aligned}$$

TC(1) = US$ 198 225.0 with C(1) = US$ 10/box
TC(2) = US$ 237 626.4 with C(2) = US$ 12/box
TC(3) = US$ 277 230.8 with C(3) = US$ 14/box
TC(4) = US$ 316 835.2 with C(4) = US$ 16/box
TC(5) = US$ 356 439.6 with C(5) = US$ 18/box
TC(6) = US$ 396 044.0 with C(6) = US$ 20/box

Imported mackerel:

- Raw material

$$\frac{1\,000\,000 \times 0.38 \times (1-0.2)}{0.67} = 453\,731 \text{ kg/2 months} = 226\,865.6 \text{ kg/month}$$

FOB costs = US$ 390/t x 453.7 t = US$ 176 943

Importation costs = US$ 210/t x 453.7 t = US$ 95 277

- Cold storage costs

For this calculation an average quantity of mackerel to be kept during the month should be estimated. Seven and a half tons are processed per day which implies a consumption of 225 t in 30 days. If, at the beginning of the first month, the quantity stored in the freezer was 453.7 t, the average quantity will be 339.35 t/day. The cost will be:

$$339.35 \text{ t} \times \frac{\text{US\$ } 1}{\text{t/day}} \times 30 \text{ days} = \text{US\$ } 10\,180.5$$

The average amount stored for the second month of production will be 117.4 t/day. Thus at the end of the month, US$ 3 522 will have to be paid. The present equivalent value for all costs (average interest rate 1% per month, $i = 0.01$) is:

$$TC = 95\ 277 + 10\ 180.5 \times (1 + 0.01)^{-1} + 3\ 522 \times (1 + 0.01)^{-2} + 176\ 943 \times (1 + 0.01)^{-3}$$

$$TC = \text{US\$ } 280\ 531 \text{ (imported)} \qquad (6.3)$$

The point of equivalence is defined in this case as the intersection of equations (6.2) and (6.3). This means that the following equation should be solved:

$$TC(x) = 19\ 822.5 \times C(x) \quad \text{(US\$)}$$
$$TC = 280\ 531 \quad \text{(US\$)}$$

The point of equivalence will be:

$$TC(x) = TC$$

from where:

$$C(x) = 280\ 531 / 19\ 822.5 = 14.152 \quad \text{US \$ / box}$$

This result indicates that the point of equivalence is reached at a cost of US$ 14.15/box of local mackerel. Costs of local raw material above this figure may induce local canneries to import raw material; below this figure, canneries will certainly buy mackerel from local fishermen. It may be useful to find the point of equivalence graphically (TC vs Ci, or TC per can vs Ci) in particular if there is an additional variable to study, for instance real interest rate (i). In Figure 6.1, the case discussed here is solved graphically and, in addition, the cases of $i = 0$ and $i = 0.03$ are added for comparison.

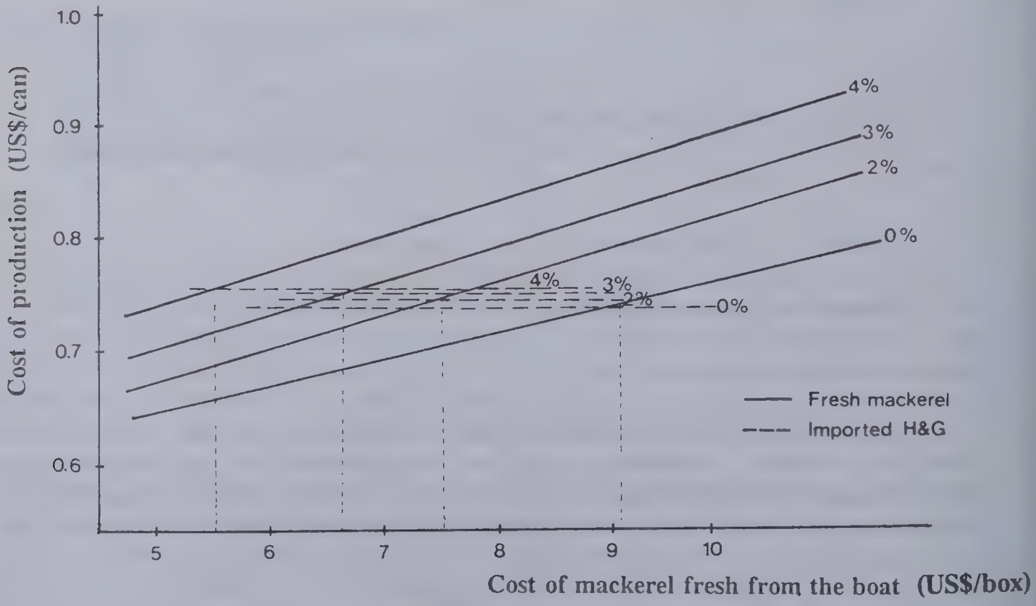


Figure 6.1 Points of Equivalence for Two Different Alternatives of Raw Material (imported and local mackerel) at Various Real Interest Rates

In this example, it is clear that the higher the real interest rate, the lower the price (US$/box) local fishermen should sell their fish to compete with imported raw material.

Example 6.4 Selection of Equipment. Fish Filleting Machines

Analyse the different technological alternatives for the mechanical processing of hake fillets.

Answer:

Annual equivalent costs were calculated for 12 mechanical lines resulting from a combination of the equipment used in industrial plants (heading, filleting and skinning machines) and refrigeration equipment in Mar del Plata (Argentina). Possibilities include local and imported equipment. Two broad groups emerge from analysis of the results; one with a type A filleting machine with less capacity and not performing the V cut, and the other with a type B filleting machine, greater capacity and speed, that performs the V cut.

The following differences are observed: yield (greater with type A filleting machine), labour utilization (greater with type A filleting machine) and investment (greater with type B filleting machine).

The values shown in Table 6.3 are for a capacity of 20 t of product daily. It is assumed that there is no variation in the overall yield of the operation. They were expressed as a function of the price of labour, which is the factor that changes most in the different countries. For example, it is observed that the price of labour in developing countries could be as much as 20 times lower than that in developed countries.

Table 6.3
Investment and Production Costs for Lines with Type A and B Filleting Machines

	Filleting Machines	
	Type A	Type B
Investment (US$)	475 750	659 174
Labour costs (US$/year)	530 690 C_L(US$/h)	484 600 C_L
Maintenance expenses (US$/year)	238 680	208 680
Fixed costs (US$/year)	777 060	911 520
Useful life (years)	10	10

The annual equivalent costs for the line with the type A filleting machine will be:

$$A_A = 475\ 750 \times F_{PA} + 530\ 690 \times C_L + 238\ 680 + 777\ 060$$

where $F_{PA\,(10\%,\,10\text{ years})} = 0.1627$ (F_{PA}, capital-recovery factor, see Appendix B Table B.2)

$$A_A = 475\ 750 \times 0.1627 + 530\ 690 \times C_L + 238\ 680 + 777\ 060$$
$$A_A = 1\ 093\ 144 \times 530\ 690 \times C_L$$
$$A_B = 659\ 174 \times F_{PA} + 484\ 600 \times C_L + 208\ 980 + 911\ 520$$
$$A_B = 1\ 227\ 747 + 484\ 600 \times C_L$$

The point of equivalence is determined by equating the annual equivalent costs:

$$A_A = A_B$$

$$1\,093\,144 + 530\,690 \times C_L = 1\,227\,747 + 484\,600 \times C_L \therefore C_L = \text{US\$ } 2.92/\text{h}$$

The cost functions and the point of equivalence are shown in Figure 6.2.

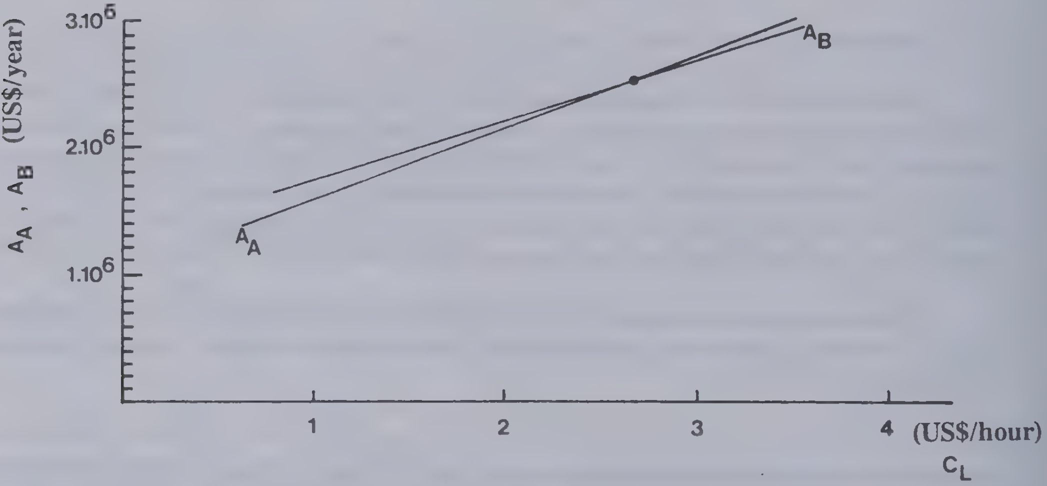


Figure 6.2 Point of Equivalence for Selection of Equipment. Hake Filleting Machines (total installed capacity 20 t raw material/day)

For labour costs higher than US$ 2.92/h (without social charges), the alternative of using the line with type B filleting machine will be the most economical; but the line with type A filleting machine will be the most convenient for labour costs lower than US$ 2.92/h.

This example shows that the installation of a mechanized fish processing line can be a function of labour costs. The drive towards more sophisticated and automated fish and shrimp processing lines in northern Europe is a result of it. However, the need for this type of studies can arise in developing countries, for instance, when insufficient qualified manpower is available or when a given level of quality or safety should be attained and kept.

6.1.3 Optimization techniques

An important characteristic of the industrial world is the continuous improvement of its operations. Optimization is the mathematical representation of this idea. Any problem in design, operation and analysis of manufacturing plants and industrial processes can be reduced, in the final analysis, to the problem of determining the maximum value of a function of different variables.

Many methods have been introduced to determine optimum processes or policies. Optimization methods provide efficient and systematic means for choosing from among infinite solutions, occurring in problems with a large number of decision variables.

Optimization techniques can encompass analytical and numerical methods, which can be chosen as a function of the nature of the objective function, and the restrictions which define the model.

In order to resolve the most common problems in the fishery industry, two techniques are widely used:

(a) Linear Programming (LP) is a mathematical tool that finds the optimum solution for the efficient use or allocation of limited resources in linear systems. It is the technique most widely used for economic analysis.

The results obtained through LP can also be acquired by determining the optimum combination of resources outlined in the micro-economic treatment of production. In this case, production requirements from a set of restrictions similar to those which define the isoquants, and the prices of the inputs are represented by the isocost lines.

Other applications of LP, such as problems of inventory control, transport, product formulation, etc., may also be mentioned.

(b) Dynamic Programming (DP) is a strategy which is especially applicable to the solution of problems with multiple stages. It allows complex problems to be broken down into a sequence of simpler sub-optimization problems. Some applications of DP are problems of replacement, shipment, allocation of capital and other inputs.

Numerical techniques have also been developed to formulate programmes and control projects. These techniques are: Critical Path Method (CPM) and Programme Evaluation and Review Technique (PERT). The latter is used in instances where it is impossible to make a precise estimate of time, costs and results, and probability and statistics concepts must be used to make predictions.

Example 6.5 Application of Dynamic Programming. Operation of an integrated fish processing plant (canning, salting and freezing)

As an example of the use of optimization techniques, an economic comparison of the operation of integrated and individual plants (Zugarramurdi and Lupin, 1976a) is presented. The integrated plant is composed of canning, salting and freezing plants. The first step in simplifying the system is to assume that the plant will process hake (annual species) and anchovy, mackerel or bonito (seasonal species) simultaneously.

By applying the Bellman principle of optimality, a sequential sub-optimization of a step-by-step process is arrived at, according to the Dynamic Programming strategy. Given that the problem can be divided into a series of identifiable steps, within each of the plants, it seems appropriate to apply this technique in the search for the optimum solution. The scheme of the system to be optimized is as shown in Figure 6.3 where:

C^A = entry of anchovy, t/day;
C^M = entry of hake, t/day;
A_C = quantity of anchovy to be processed in the canning plant, t/day;
A_S = quantity of anchovy to be processed in the salting plant, t/day;
A' = entry of anchovy in the salting and freezing plants, t/day;
A_F = quantity of hake to be processed in the freezing plant, t/day;
G_C = risk profit of the canning plant, US$/year;
G_{FS} = risk profit of the freezing and salting plants, US$/year.

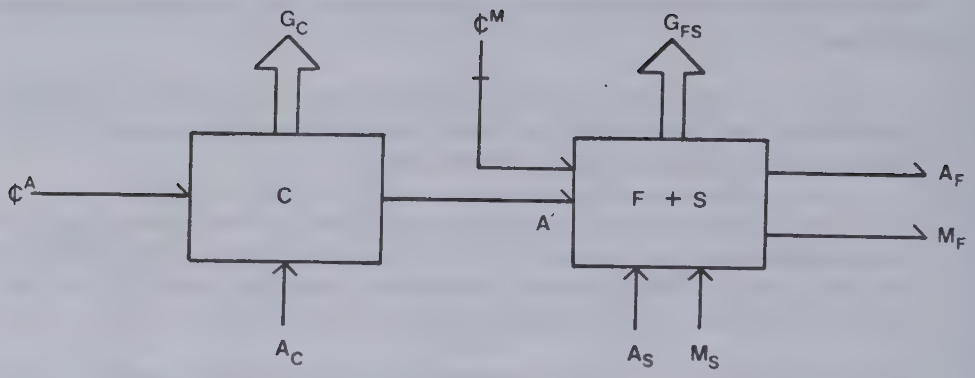


Figure 6.3 Dynamic Programming: Information Flow

In this plan, freezing and salting plants have been considered together, with the restriction that all raw material received must be processed. The plan is currently much simpler, as hake has not been considered as raw material for the canning plants over the last few years. If this option was considered, the proposed system would be modified, with the introduction of the variable C^M in the block corresponding to the canning plant, and another design variable, M^C, being introduced in the same block.

The definition of any optimization problem is to maximize or minimize (optimize) the objective function acting on the decision variables, considering all the restrictions of the system to be optimized. The problem can thus be stated as follows:

- The objective function is the optimum operation of an integrated plant producing frozen, salted and/or marinated, canned and fishmeal products. As it is an existing plant, with a defined production capacity, the criterion to be used will be the maximization of the risk profit function. The mathematical expression for each individual plant is:

  $\text{Ma x } G = NP - i \times I_w - (i + h) \times I_F$

where:

G = risk profit
NP = net profit
i = rate of return
I_w = working capital
h = level of risk
I_F = fixed investment

- Design variables: Quantities of anchovy and hake to be processed in each plant.

- Restrictions for each step: The quantities of each species that each plant can process will be determined by its maximum value and in no case will exceed the total capacity of the plant in question (restriction 1). It is assumed that the total entry of raw material is always less than the total quantity which the integrated plant can process; if not, the excess is sent to the raw material cold storage freezer (restriction 2).

Once the problem has been presented in this way, it is obvious that there are infinite possibilities for the distribution of raw material among the different plants. The use of the Dynamic Programming technique allows the optimum combination of variables for each entry value of raw material to be known. The Bellman Principle of Optimality indicates that the last step (salting and freezing) must be optimized with respect to the supply that it receives from the variables A' and C^M. This means that the value of A_S and M_S which succeeds in maximizing the partial objective function G_{FS} for any value of C^M and A' is optimum.

Once the final step is optimized, the value of A_C, which will maximize the partial function of the canning step, plus the maximum of the last function, must be chosen.

The last step of this calculation strategy is the collection of the information in order to prepare an optimum plan for the operation of the integrated plant, as a function of the raw material entering the plant daily. This is outlined in the following calculation sequence:

Data = C^A and C^M

(a) From the graph or table resulting from the optimization of the canning stage, the optimum value of A_C^* is obtained.

(b) $A' = C^A - A_C^*$

(c) From the table or graph resulting from the optimization of the salting and freezing steps, with the values of A' and C^M, optimum values of A_S^* and M_S^* are obtained.

(d) From the design relationship in this last step, one obtains:

$$A_F^* = A' - A_S^*$$

$$M_F^* = C^M - M_S^*$$

Table 6.4 lists the values of the design variables for a integrated plant and the corresponding values for individual plants. In both cases the operation is taking place with a saturation of raw material (C^A = 184.5 t/day and C^M = 34.5 t/day). A point to be discussed is the inclusion of the fishmeal plant. If it is added to the integrated plant (which is logical) the costs of raw material will be practically nil, since it will use trimmings, remains and material discarded by the other plants. If the individual plant operates with trimmings and remains, it will have to buy them.

The profit of the integrated plant compared to the individual plants working separately, when the fishmeal plant is not included, is increased by 28%, while if it is included, the profit would increase by 57%. It should be pointed out that eventually an integrated plant can operate with only one of its production lines, in this case the frozen line, with a profit lower than that of an equivalent plant operating alone.

This situation occurs, since the optimum point of all the plants taken together is not necessarily equal to the sum of the optimum points of the individual plants. As a result, the quantities to be processed in the integrated plant do not correspond to the maximum of the individual plants, but to those which result from the application of the method of dynamic programming to the system. On the other hand, the application of this method can be extended to determine the form in which costs will vary for a similar product manufactured by an individual plant and an integrated one. The result is a reduction of unit costs. For example, for the manufacture of canned products, the unit cost of the product in the integrated plant will be 20% lower than in the individual canning plant.

Table 6.4
Comparison of an Integrated Plant with Individual Plants

Plant	Individual Plants Optimum Value (t/day)	Integrated Plants Optimum Value (t/day)
Canning	$A_C = 150$	$A_C = 131.1$
Salting	$A_S = 4.32$ $M_S = 4.68$	$A_S = 4.4$ $M_S = 4.6$
Freezing	$A_F = 31.78$ $M_F = 28.22$	$A_F = 49$ $M_F = 30$

Although optimization techniques are, with few exceptions, not utilized in developing countries, they are utilized in developed countries by medium and large food and fish companies, and consultant companies which provide technical advice to the fishery industry.

Optimization techniques require a sound technical and analytical knowledge of the system to be optimized. In most cases, it means the possibility to develop a mathematical model incorporating the most relevant variables. Application of optimization techniques is relatively common in today's most developed fishery industries.

The on-line simulation for product management that Scandinavian fishery industries expect to introduce by 1995 is basically a real time optimization programme. Some fish processing machines and equipment have already incorporated optimization techniques, e.g., in the robots that utilize vision techniques to eliminate bones and portion fillets. Optimization is also already implicitly incorporated at the design stage in multi-stage compressors in refrigeration and multi-stage evaporators of fishmeal plants, improving efficiency and reducing costs.

Optimization techniques have also been used, for instance, to calculate sterilization (or pasteurization) times in canned products, maximizing nutrient retention or texture characteristics, and to optimize packaging design (e.g., maximum strength vs minimum packaging material). In countries where information on nutrient composition on the labels is mandatory, as in the USA, processes that optimize nutrient retention are essential. In most cases, such procedures are the result of applied research at company level and therefore not available to the public.

Optimization techniques are also utilized in the design and production of fish feed for aquaculture in order to obtain a maximum in nutrient value at a minimum cost with the available raw materials. Optimization techniques are a part of modern management techniques. Although they are not yet a customarily used tool of the fish technologist in developing countries, they should be incorporated as such if self-sustainability is sought. The next step to the use of economic engineering is the application of optimization techniques.

7. PROFITABILITY

7.1 Profit of a Business

"Profitability" is a general term which measures the income that can be earned in a particular situation. It is the common factor in all productive activities. Some parameters need to be introduced in order to define profit. Gross profit (GP) for the company equals the income from total sales (S) less total production costs without depreciation (C), as follows:

$$GP = S - C \tag{7.1}$$

When considering depreciation costs, net profit before taxes (NPBT) results:

$$NPBT = GP - e \times I_F = S - C - e \times I_F \tag{7.2}$$

where: e = internal depreciation factor.

Taxes are imposed on these gross earnings such that the investor does not receive the entire sum of money. They constitute an important factor in evaluating the economy of alternative courses of action. The level of taxation differs in each country, for example (French Institute of Petroleum, 1981):

Country	Percentage
USA	52
Canada	41
Germany	51
France	50
Italy	35
UK	53.75
Japan	50

For example, the rate of taxation in 1980, in USA, was applied in the following way (Jelen and Black, 1983):

	Percentage
Rate on the first US$ 25 000 earned:	17
Rate on the next US$ 25 000 earned:	20
Rate on the next US$ 25 000 earned:	30
Rate on the next US$ 25 000 earned:	40
Rate on earnings above US$ 100 000:	46

The same type of situation can be found in developing countries. For instance, in 1969, the following taxation scale was used in Peru (Engstrom, *et al.*, 1974):

	Percentage
For income under US$ 2 326	20
Income between US$ 2 326 and 11 628	30
Income above US$ 11 628	35

It is noted that taxation levels and procedures change in some countries frequently (e.g., yearly). When it is not possible to determine the actual tax, an arbitrary tax of 40-50% of net profit before taxes is suggested. Net Profit (NP) can be calculated as follows:

$$NP = S - C - e \times I_F - t\,(S - C - d \times I_F) \tag{7.3}$$

where: d = official depreciation factor and t = taxation rate.

The passage of money into or out of the enterprise is called cash flow and is defined as the difference between income and operating costs, excluding depreciation and after payment of taxes; it can be expressed as follows:

$$\begin{aligned} CF &= NP + e \times I_F = S - C - t \times (S - C - d \times I_F) \\ &= GP - t \times (S - C - d \times I_F) \end{aligned} \tag{7.4}$$

Cash flow or net profit is not a measure of profitability but these figures are used to calculate profitability of a particular project. The aim of an investor or company is always to maximize earnings with respect to the costs of the capital to be invested. If the aim were solely to maximize earnings, any investment that might yield profits would be acceptable, despite low returns or high costs.

In economic studies where different alternatives for a project have to be compared, or a comparison made between the profitability of a project and the profitability of existing financial transactions, methods of analysis are used that will allow this estimate to be made on a uniform basis.

7.2 Cash Flow Diagrams

All investment projects indicate an action that will develop over a number of years in the future. The study of the financial characteristics of a project requires analysis of the time value of money, financial risk, future variations in sale prices, costs, volume of sales and taxation rate, and the time needed to implement the project or install the equipment before starting normal production and the economic life of the project. Such factors are the following:

I_F = Depreciable Original Fixed Investment
I_W = Working Capital
I_R = Residual Investment = Land + I_W
A = Annual Earnings
B = Annual Cash Generation from Depreciation
C = Construction Period

A way of visualizing many of these factors is to use a cash flow diagram like that shown in Figure 7.1 (Perry and Chilton, 1973).

In Figure 7.1, money is shown on the y-axis and time on the x-axis. Zero time is the point at which the plant begins to produce. In negative situations, the only cash flow is negative, as this is the money paid for land and fixed investment, I_F. When the process is ready to begin, there is an additional quantity of money to consider within working capital, I_W. When the process begins production, the money enters the project as a product of sales, S. The cash flow accumulates, moving from negative to positive, and when the project ends, the capital invested in current assets and land is recovered, resulting in a positive final cash flow.

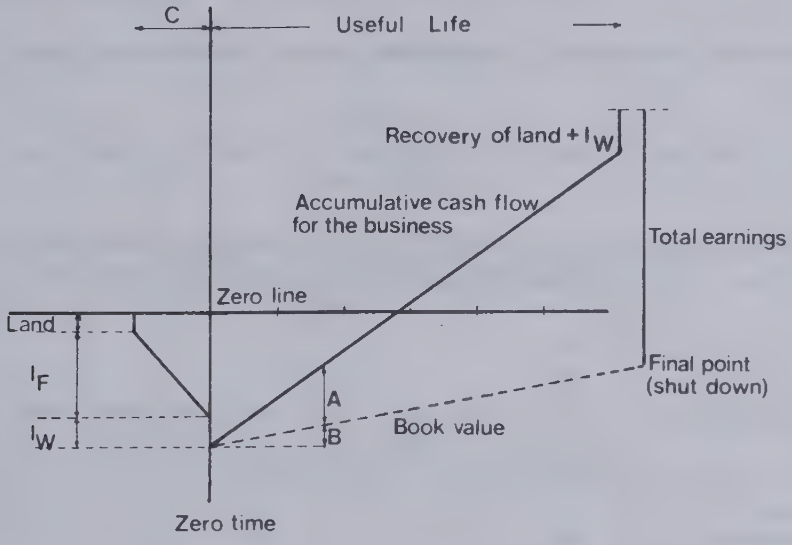

C
Useful Life
Recovery of land + I W
Accumulative cash flow for the business
Total earnings
Zero line
Land
I F
I W
A
B
Book value
Final point (shut down)
Zero time

Figure 7.1 Cumulative Cash Flow for a Project

This diagram has the advantage of showing all financial characteristics, with the except for risk, the rate at which the project generates money and the earnings for re-investment.

7.2.1 Statements of sources and application of funds

Financial plans can be simply presented by integrating all data into "statements of sources and application of funds". These statements show the origin or source of the funds and their final destination.

Example 7.1 Statements of Sources and Application of Funds

Prepare a statement on the sources and application of funds for the frozen hake plant in Example 2.1.

Data: I_F = US$ 600 000 (from Example 3.1)
I_W = US$ 60 000 (from Example 3.1)
Daily Production = 2 t FB
Working days of the year = 270
N = 10 years
Selling price = US$ 1 560/t FB
Unit Production cost = US$ 1 272 /t FB (Example 4.4)

Answer:

Annual sales = Annual Production (t FB/year) x Selling Price (US$/t FB) =
= 2 t FB/day x 270 days/year x 1 560 US$/t FB =
= 540 t FB/year x 1 560 US$/t FB = 842 400 US$/year

Annual production cost = Annual production (t FB/year) x Unit production cost (US$/t FB)

= 540 t FB/year x 1 272 US$/t FB = 686 880 US$/t FB

The straight-line method of depreciation is used. The results are given in Table 7.1.

Table 7.1
Statement of Sources and Application of Funds for a Fish Plant
(in US$ '000)

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Source										
Own capital	480									
Bank credit (*)	180									
Net sales from activity	842	842	842	842	842	842	842	842	842	842
Total (a)	1 502	842	842	842	842	842	842	842	842	842
Applications										
Fixed investment	600									
Working capital	60									
Costs of financing (**)	27									
Costs of production	687	687	687	687	687	687	687	687	687	687
Total (b)	1 374	687	687	687	687	687	687	687	687	687
(a) - (b)	129	156	156	156	156	156	156	156	156	156
Net profit (***)	77	93	93	93	93	93	93	93	93	93
Plus depreciation	60	60	60	60	60	60	60	60	60	60
Cash flow	137	153	153	153	153	153	153	153	153	153

Notes:

(*) There is a bank credit, 30% I_F= US$ 180 000.
(**) Bank rate on loan 15% per year. For simplicity, only a one year credit has been considered.
(***) Taxes to be deducted from earnings (40%).

7.3 Methods of Estimating Profitability

The most common methods of evaluating profitability are the following:

- Rate of return on the original investment (i_{ROI}).
- Rate of return on average investment (i_{RAI}).
- Present-worth (PW)
- Internal rate of return (r)
- Pay out time (n_R)

7.3.1 Rate of return

In economic engineering studies, the rate of return on investment is normally expressed as a percentage. The annual net profit divided by total initial investment represents the fraction which, when multiplied by 100, is known as the percentage return on investment. The usual procedure is to find the return on total original investment, with the value of the average net profit being the numerator:

$$NP_a = \frac{1}{n} \times \sum_{j=1}^{n} NP_j \tag{7.5}$$

and thus, the rate of return on the original investment, i_{ROI}, will be:

$$i_{ROI} = \frac{NP_a}{I_T} \tag{7.6}$$

Due to the depreciation of the equipment during its useful life, it is usual to relate the rate of return to the average investment estimated during the useful life of the project. Average investment (I_a) is found as follows:

$$\text{Average investment} = I_a = \frac{1}{n} \times \sum_{k=0}^{n} B_k \tag{7.7}$$

where B_k = Book value in year k.

It can also be used an approximate formula to calculate the average investment:

$$I_a = I_F / 2 \tag{7.8}$$

The rate of return on the average investment (i_{RAI}) can be determined by the following equation:

$$i_{RAI} = \frac{NP_a}{I_a + I_W} \tag{7.9}$$

The method to calculate the rate of return on the original investment (i_{ROI}) is also known as the engineering method, while the method that calculates the rate of return on the average investment (i_{RAI}) is the method preferred by accountants.

These methods give "point values" which are applicable in a particular year or for some "average" year chosen. No account is taken of inflation, or of the time value of money.

Example 7.2 Calculation of Rate of Return on Original Investment (i_{ROI})

Calculate the rate of return on original investment for the frozen hake plant in Example 7.1.

Answer: In this case where the annual cash flows are not constant, the following must be calculated:

$$\text{Average annual net profit} = \text{Annual cash flow} - \text{Annual depreciation costs} \tag{7.10}$$

The resulting values are shown in Table 7.2

Table 7.2
Calculation of Average Annual Net Profit for the Plant in Table 7.1

Year	Average Annual Profit (US$)
1	77 000
2	93 000
3	93 000
4	93 000
5	93 000
6	93 000
7	93 000
8	93 000
9	93 000
10	93 000
Total	91 400 ÷ 10 = 9 140

The average rate of return on the original investment will be:

(9 140 ÷ 660 000) x 100 = 13.8% per year

The time value of money is not considered, since only the average profit is used, not its timing. The profits from years 1 through 10 could be reversed and the return on original investment would be the same.

Example 7.3 Calculation of Rate of Return on Average Investment (i_{RAI})

Calculate the rate of return on average investment for the frozen hake plant in Example 7.1.

Answer: In order to correctly determine the average investment, the average investment must be calculated according to Table 7.3.

Table 7.3
Calculation of Average Investment for the Plant in Table 7.1

Year	Investment (US$)
1	600 000
2	600 000 - 60 000 = 540 000
3	546 000 - 60 000 = 480 000
4	492 000 - 60 000 = 420 000
5	420 000 - 60 000 = 360 000
6	360 000 - 60 000 = 300 000
7	300 000 - 60 000 = 240 000
8	240 000 - 60 000 = 180 000
9	180 000 - 60 000 = 120 000
10	120 000 - 60 000 = 60 000
Total	3 300 000 ÷ 10 = 330 000

From Table 7.3., the divisor of Equation (7.9) is:

$$I_a + I_W = \text{US\$ } 330\,000 + \text{US\$ } 60\,000 = \text{US\$ } 390\,000$$

and the rate of return on average investment, will be:

$$\frac{91\,400}{390\,000} \times 100 = 23.4\% \text{ per year}$$

Making an approximation with equation (7.8), it can be seen that:

$$\frac{91\,400 \times 100}{\dfrac{600\,000}{2} + 60\,000} = 25.4\%$$

which shows a 8.5% error in the estimate. The time value of money is not considered, since only the average investment is used, not its timing.

7.3.2 Present-worth (PW)

This method compares the present-worth (PW) of all the cash flows with the original investment. It assumes equal opportunities for re-investment of the cash flows at a pre-assigned interest rate. This rate can be taken as the average value of the rate of return on the capital of the company or designated as the minimum return acceptable for the project. The procedure followed compares the magnitude of present-worth of all revenues with investment at time 0. The net present value is a single amount referred to zero time and represents a premium if positive, or a deficiency if negative, at a chosen fixed rate of return.

$$PW = \sum_{j=1}^{n} \frac{CF_j}{(1+i)^j} - I_T \tag{7.11}$$

Present-worth can also be defined as the additional amount that will be required at the beginning of the project, at a pre-assigned interest rate, to produce income equal to, and at the same time as, the prospective investment. Results do not indicate the magnitude of project. For that reason, the ratio of the discounted cash flow to investment is also suggested as a criterion (Equation 7.12)

$$PW' = \frac{\displaystyle\sum_{j=1}^{n} \frac{CF_j}{(1+i)^j}}{I_T} \tag{7.12}$$

This relationship can be used as an indicator of the profitability of the project by analysing the difference between the result and the unit value. The unit will be found where the pre-determined rate coincides with the value of the internal rate of return (see section 7.3.3). The results from both calculations (Equations 7.11 and 7.12) can give some idea of the total magnitude of the project.

Example 7.4 Calculation of Present-worth

Calculate: (a) the present-worth (PW) and (b) the PW' relationship for the frozen hake plant in Example 7.1.

Answer: Applying a rate of i = 15% per year in Equation (7.11), the following results are obtained:

$$\sum_{j=1}^{10} \frac{CF_j}{(1+0.15)^j} = \frac{137\ 000}{(1.15)^1} + \frac{153\ 000}{(1.15)^2} + \ldots. + \frac{(153\ 000 + 60\ 000)}{(1.15)^{10}} = \text{US\\$ } 770\ 182$$

It should be noted that the salvage value and working capital must be included with the last year cash flow.

(a) PW = US$ 770 182 - US$ 660 000 = US$ 110 182

At the end of ten years, the cash flow to the project, compounded on the basis of end-of-year income, will be:

$$F = 137\ 000 \times (1.15)^9 + 153\ 000 \times (1.15)^8 + 153\ 000 \times (1.15)^7 +$$

$$+ 153\ 000 \times (1.15)^6 + 153\ 000 \times (1.15)^5 + 153\ 000 \times (1.15)^4 +$$

$$+ 153\ 000 \times (1.15)^3 + 153\ 000 \times (1.15)^2 + 153\ 000 \times (1.15) + 213\ 000$$

$$= \text{US\\$ } 3\ 115\ 816$$

This amount represents the future worth of the proceeds to the project and must equal the future worth of the initial investment plus the present-worth compounded at an interest rate of 15% per year.

$$F = (660\ 000 + 110\ 182) \times (1.15)^{10} = \text{US\\$ } 3\ 115\ 816$$

Thus, when US$ 110 182 is added to the investment (US$ 660 000) the result will be the sum that should be invested, at 15%, to generate annual income equal to, and at the same time as that estimated by the recommended investment.

(b) The relationship between the present-worth of the annual cash flow and the total investment, from Equation (7.12):

$$PW' = \frac{770\ 182}{660\ 000} = 1.17$$

7.3.3 Discounted cash flow rate of return (DCFRR)

This method takes into account the interest on the money invested, with time, and is based on the part of the investment that has not been recovered at the end of each year during the useful life of the project.

A trial and error method is used to establish the interest rate to be applied to the cash flow each year, such that the original investment would be reduced to zero (or salvage value, plus land, plus working capital) during the useful life of the project.

In such a case, the resulting rate of return, is equivalent to the maximum interest rate that could be paid to obtain the necessary funds to finance the investment and completely paid back by the end of the useful life of the project.

Therefore, in this method, the present-worth of all cash flows is taken as zero and the internal rate of return, r, is calculated by trial and error:

DCFRR = IRR = r, where:

$$\sum_{j=1}^{n} \frac{CF_j}{(1+r)^j} - I_T = 0 \tag{7.13}$$

It should be noted that the application of computer technology to the preparation of feasibility estimates has become commonplace. Profit-estimating computer systems have a wide variety of applications, being used to increase accuracy and to reduce the time and cost of preparing capital-cost and profit estimates.

Example 7.5 Calculate the Internal Rate of Return (r)

Calculate the internal rate of return for the frozen hake plant in Example 7.1.

Answer: At the end of 10 years, the present-worth of the cash flows (expressed dollars) will be:

$$PW = \frac{137\,000}{(1+r)^1} + \frac{153\,000}{(1+r)^2} + \ldots\ldots + \frac{(153\,000 + 60\,000)}{(1+r)^{10}} \tag{7.14}$$

which is equal to the present-worth of the initial, fixed investment, plus working capital.

$$PW = I_F + I_W = \text{US\$ } 660\,000 \tag{7.15}$$

An internal rate of return is obtained by making equation (7.14) equal to equation (7.15) and finding the value of r by trial and error. As mentioned before, this trial and error search can be done by computer, but in its absence, a discount factor is normally applied to the annual cash flows, in order to obtain the present-worth by applying various values of r, until the required value of the investment is obtained.

The discount factor for payments at the end of year M, is:

$$d_M = \frac{1}{(1+r)^M} \tag{7.16}$$

where:

r = selected interest rate
M = year for which the calculation is done.

Table 7.4 shows the trial and error method used in the example.

Table 7.4
Calculation of Internal Rate of Return for the Fish Plant in the Example 7.1

Year (m)	Cash Flow (US$ '000) d_m	Trial for r = 0.1		Trial for r = 0.2		r = 0.19	
		Factor	Present-worth (US$ '000)	Factor d_m	Present-worth (US$ '000)	Factor d_m	Present-worth (US$ '000)
0	(660)						
1	137	0.909	125	0.833	114	0.840	115
2	153	0.826	126	0.694	106	0.705	108
3	153	0.751	115	0.579	89	0.592	91
4	153	0.683	104	0.482	74	0.497	76
5	153	0.621	95	0.402	61	0.417	64
6	153	0.564	86	0.335	51	0.350	54
7	153	0.513	78	0.279	43	0.294	45
8	153	0.466	71	0.232	35	0.247	38
9	153	0.424	65	0.194	30	0.207	32
10	213	0.385	82	0.162	35	0.174	37
Total			948		638		660
Relationship = $\frac{\text{Total Present-worth}}{\text{Original Investment}}$			1.44		0.97		1.00

The interpolation to determine the correct value of r can be done by plotting the relationship between the original investment and the Total Present-worth as a function of r, as is shown in Figure 7.2.

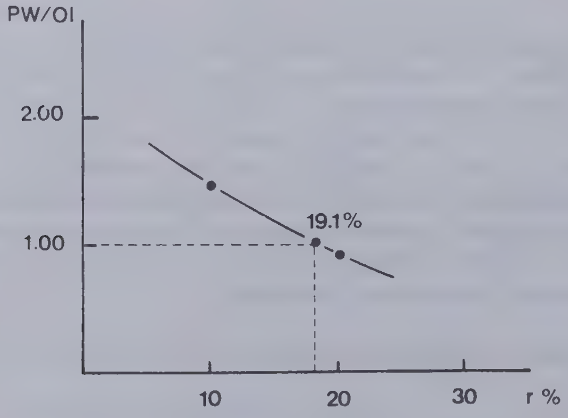


Figure 7.2 Interpolation for the Calculation of r, using the Values of Table 7.4

For simplicity, some columns for the d_M factor have been omitted in Table 7.4. The 19.1% rate of return is the interest rate at which the original amount of US$ 660 000 could be invested to generate income similar to, and at the same time as those calculated for the proposed investment. Thus,

1) 660 000 x 1.19 = 785 697; 785 697 - 137 000 = 648 697
2) 648 697 x 1.19 = 772 241; 772 241 - 153 000 = 619 241
3) 619 241 x 1.19 = 737 176; 737 176 - 153 000 = 584 176
4) 584 176 x 1.19 = 695 432; 695 432 - 153 000 = 542 432
5) 542 432 x 1.19 = 645 738; 645 738 - 153 000 = 492 738
6) 492 738 x 1.19 = 586 580; 586 580 - 153 000 = 433 580
7) 433 580 x 1.19 = 516 156; 516 156 - 153 000 = 363 156
8) 363 156 x 1.19 = 432 319; 432 319 - 153 000 = 279 319
9) 279 319 x 1.19 = 332 515; 332 515 - 153 000 = 179 515
10) 179 515 x 1.19 = 213 000; 213 000 - 213 000 = 0

It should be emphasized that the internal rate of return calculated for the plant in the example is lower than the rates observed for similar but larger plants. This result, in agreement with reality, is justified by the concepts discussed in Chapter 5.

7.3.4 Pay out time (n_R)

Pay out time is defined as the minimum period of time theoretically necessary to recover the original investment in the form of cash flow from the project, based on total receipts less costs and excluding depreciation. Generally, the original investment only includes the initial, fixed, depreciable investment.

$$\text{Pay out time, in years} = \frac{\text{Fixed Depreciable Investment}}{(\text{average profit/year}) + (\text{average depreciation/year})} \qquad (7.17)$$

$$\text{Average Cash Flow} = CF_a = \frac{1}{n} \times \sum_{j=1}^{n} CF_j \qquad (7.18)$$

$$\text{Pay out time, } n_R = \frac{I_F}{CF_a} \qquad (7.19)$$

Example 7.6 Calculation of Pay out Time (n_R)

Calculate the pay out time for the frozen hake plant in Example 7.1.

Answer: The application of this method to the data in Table 7.1., gives the time required to reduce the investment to zero. From Equation (7.17):

$$n_R = \frac{600\ 000}{151\ 400} = 3.96 \text{ years}$$

which is an approximate value only coinciding with real value when cash flows are equal.

Table 7.5 shows that the investment will be reduced to zero between 4 and 5 years.

Table 7.5
Accumulated Cash Flow for the Plant in Table 7.1

Year	Cash Flow (US$)	Accumulated Cash Flow (US$)
0	-600 000	- 600 000
1	137 000	- 463 000
2	153 000	- 310 000
3	153 000	- 157 000
4	153 000	- 4 000
5	153 000	149 000
6	153 000	302 000
7	153 000	455 000
8	153 000	608 000
9	153 000	761 000
10	153 000	914 000

Values of Table 7.5 are plotted in Figure 7.3. This figure shows the graphical interpolation which gives a pay out time of 4.05 years. This is the real value of n_R.

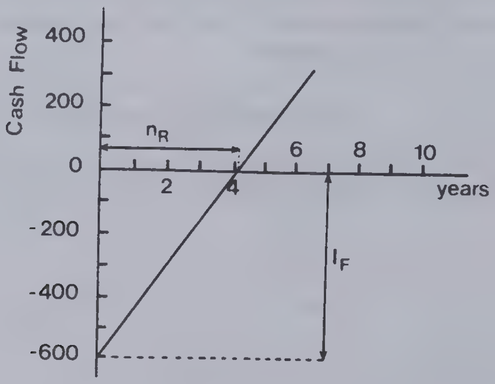


Figure 7.3 Graphical Interpolation for Obtaining Pay Out Time

7.4 Risk Consideration

Capital investments are made with the expectation of obtaining a substantial annual profit, but the possibility that losses might be incurred always exists. This factor, which accompanies all investments, is called "risk". In general, the greater the risk, the higher the expected rate of return and the shorter the time foreseen to recover of the investment.

Table 7.6, which gives average values for risk-free annual rates of return on capital investments for processing industries, allows comparisons to be made with the results of new feasibility studies on the expansion or modification of existing plants (Rudd and Watson, 1968; Woods, 1975).

Table 7.6
Average Profitability Values for Risk-Free Capital for Processing Industries

Industry	Annual rate (%)
Public utilities (electricity and gas)	6.3
Telephone companies	6.8
Steel (USA)	7.5
General Motors	7.8
Standard Oil	8.2
Cellulose and paper, rubber	8-10
Synthetic fibres, chemical and petroleum products	11-13
Drugs and pharmaceutical products, extraction and mining industry	16-18

From Equation (7.3), with d equal to e and constant, the Net Risk Profit (NRP) is defined as:

$$NRP = (S - C - d \times I_F) \times (1 - t) - i_M \times (I_F + I_W) \qquad (7.20)$$

In Table 7.7, the minimum acceptable rate of profitability (i_M) is shown as a function of the degree of risk (Happel and Jordan, 1981).

Table 7.7
Quantification of Risk

Type of Project	Degree of Risk	i_M (%)
Short project, modification of existing plants Working capital, land	low	10-15
Specific equipment Medium-term projects	moderate	15-25
Automatic instrumentation New installations for a new product	high	20-50 or more

A result higher than zero indicates that the project has an annual profitability that exceeds the minimum acceptable rate, even when risk is taken into consideration. This method does not consider the temporal value of money, but more complete equations, such as the risk-value method, are given in the literature (Happel and Jordan, 1981).

Example 7.7 Calculation of Net Risk Profit (NRP)

Calculate the net risk profit for the frozen hake plant in Example 7.1.

Answer: A minimum acceptable profitability rate of 10% was selected from Table 7.1. This is considered a low risk alternative. From Equation (7.20):

$$NRP = 91\,400 - 0.10 \times 660\,000 = US\$\ 25\,400$$

A result greater than zero indicates that the project has an annual profitability that exceeds the minimum acceptable rate, even when risk is taken into consideration. It will be left to the reader to determine the profitability of the canning plant in Example 2.2, by using the same methods employed in Examples 7.1 to 7.7.

Data: I_F = US\$ 130 000 (from Example 3.2)
I_W = US\$ 13 000 (from Example 3.2)
Daily Production = 2 670 cans
Working days of the year = 250
n = 10 years
Selling price = US\$ 0.8/can
Unit Production cost = US\$ 0.68/can (Example 4.5)

7.5 Advantages and Disadvantages of the Different Methods of Estimating Profitability

Methods of return on fixed investment or on average investment give static values that can yield misleading results. These "point values" are either applicable for one particular year or for "average" years. Nevertheless, they are the easiest way to a quick estimate. Pay out time does not adequately account for the last years of useful life of the project. On the other hand, the internal rate of return method considers the time value of money and produces more realistic results than other methods. If there are investments after start-up time, the present-worth is the method that should be used, as the internal rate of return method gives multiple results.

What is the best profitability criterion? In practice, the analyst does not use a single criterion, but considers the use of various criteria to compensate for the advantages and disadvantages of each. Table 7.8 gives reasonable values for pay out time and internal rate of return for projects with different degrees of risk (Cunningham, 1980).

Table 7.8
Typical Values for Pay-out Time and Internal Rate of Return as a Function of Risk

Project	Pay out time (years)	Internal rate of return (%)
High risk	< 2	> 20
Normal	< 5	15
Slight risk		< 10

Key factors which affect profitability of operations in fish plants are generally cost and quality of raw material and the yield from processing, as long as the raw material is available and the market for the resulting products is stable (Montaner and Zugarramurdi, 1994).

7.6 Break-even Analysis

Break-even analysis is a method of organizing and presenting some of the static, short-run economic relationships of a business. Economic production charts show how costs, sales, and profits will vary when the rate of production changes, other things being equal. These evaluations do not take into account the time value of money and data for decisions are believed to be acceptably accurate.

The best known break-even model relates fixed and variable costs to revenue for the purpose of profit planning. In general, the efficiency of production operations depends on the utilization of the plant. When the profit can be defined as a function of the level of production of the system, it is possible to select the level of production at which profits will be highest. Mathematically, calculations are:

- Total Revenue = Selling Price (US\$/unit) x Production Rate (unit/time) =
  $= P \times Q$ (7.21)

- Total Costs =
  = Variable Cost (US\$/unit) x Production Rate (unit/time) + TFC (US\$/time) =
  $= V \times Q + TFC$ (7.22)

- Net profit before taxes = NPBT = Total Revenue - Total Costs =
  $= P \times Q - (V \times Q + TFC)$ (7.23)

At the break-even point, profits equals zero and the output to break even can be calculated as follows:

$$Q = TFC / (P - V) \tag{7.24}$$

The value Q indicates the volume at which revenue and total operating cost exactly break even. At this point, one additional unit made and sold would produce a profit. Until the breakpoint is attained, the producer operates at a loss. The effects of production rate and operating time on costs should be recognized. By considering sales demand along with the capacity and operating characteristics of the equipment, the analyst can recommend the production rates and operating schedules that will give the best economic results.

It is generally accepted that firms seek to maximize profit. The majority of micro-economic theories consider the firm as a profit maximizing entity. In the short-run during which output level can be varied but plant size cannot, the firm is faced with several alternatives of levels of production, each with different profits, so the alternative with the greatest expected earnings will be selected.

The quantity that the firm will produce depends on the characteristics of the market. In a perfectly competitive market, the equilibrium is reached at a total industry output of Q_T and at a price of P^*. Each firm has a horizontal demand which intersects the vertical axis at the equilibrium price (P^*). In this case, both marginal and average revenue are constant and $P^* = MR = AR$.

All these relationships are shown in Figure 7.4.

Given that the firm can sell any quantity of product (Q) at the same price, its total revenue (TR) will be a line with a positive slope that begins at the origin. If the firm has a cost structure represented by the following curves: average total cost (ATC), marginal cost (MC), total fixed cost (TFC) and total cost (TC), what will be the total quantity (Q^*) that the firm will decide to offer for sale, and what will be the profit in that case?

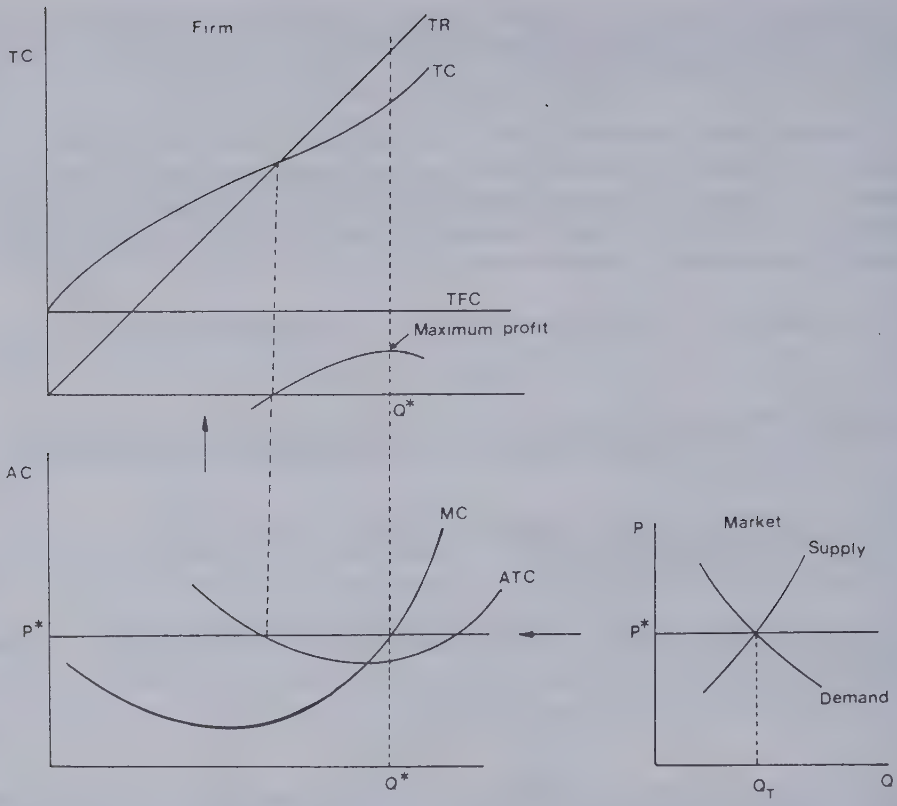


Figure 7.4 Equilibrium in the Short Run for a Firm Operating in a Perfectly Competitive Market

The response to these questions requires consideration of the aims of a firm producing in an environment of perfect competition: to maximize profits or to minimize losses. The easiest way of determining the point at which profits are maximized is to compare total revenue and total costs or to equal marginal revenue (MR) and marginal cost (MC). This rationale is shown in Figure 7.4. The firm maximizes profit by selling a quantity (Q*) for which MC = P*. The vertical distance between the total revenue line and the total cost curve indicates the profit. It will be maximum when Q* is the number of units produced. The firm's profit function is derived by subtracting TC from TR at each rate of output. In this system, it is also possible to incur losses in the short run and still continue producing, depending on the level of prices in the market and when this alternative will mean fewer losses than shutting down production entirely.

Figure 7.5. shows the case that a firm is facing by lower and lower P. Whether the firm realizes a profit or a loss depends on the relationship between price and average total cost at the intersection of MR and MC. The quantities to produce (Q_d, Q_c , Q_b and Q_a) for each different level of prices (P_d, P_c , P_b and P_a) are determined as:

Price = Marginal Cost

- The point (Q_d, P_d) maximizes profit due to price P_d exceeds ATC.
- The point (Q_c, P_c) is a break-even point, profit equals zero. The price P_c equals ATC.

- The point (Q_b, P_b) minimizes its short-term losses due to price P_b is less than ATC but higher than AVC. So, the TFC are paid and the TVC are partially recovered.
- The point (Q_a, P_a) is a shutdown point, negative profit equals TFC or P_a = AVC. Short-run losses equal to TFC will be incurred if production is temporarily ceased.

This conclusion is useful for deriving the supply curve for the firm in the short run (see Figure 7.5). Profit-maximizing firm's supply curve is its rising Marginal Cost curve.

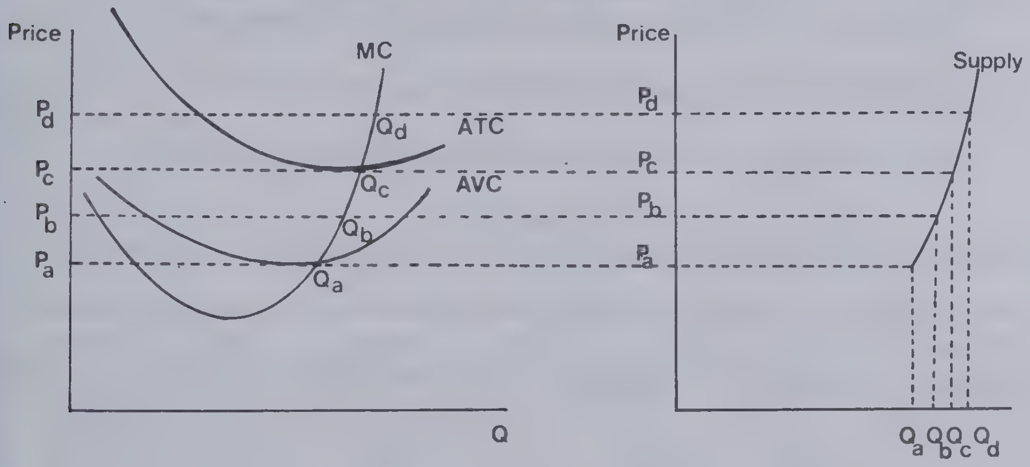


Figure 7.5 Supply Curve in the Short Run for a Firm Operating in a Perfectly Competitive Market

In the short run, a firm's capacity is limited by its fixed inputs, whereas in the long run, the options are numerous: its size can change, new technologies implemented, or the characteristics of its products can change according to changes in consumer tastes. As an extrapolation of these concepts, each business can determine its supply curve in the long run. In reality variations do occur, depending on the structure of the competition; that is, whether there are few or many suppliers or depending on whether the products are identical or varied. Four types of market structure can be identified:

- Perfect Competition : many sellers of a standardized product
- Monopolistic Competition : Many sellers of a varied product
- Oligopoly : Few sellers of a standard or varied product
- Monopoly : Single seller of a product for which there is no substitute.

Example 7.8 Determination of the Break-even Point for a Frozen Fish Plant

Analyse the frozen hake plant in Example 2.1. Plot the total costs, variable costs, fixed cost and income from sales curves on a graph and determine the break-even point.

Answer: Data:

Selling price = US$ 1 560/t of frozen fillet blocks
Unit Production cost = US$ 1 272/t FB (Example 4.4)
Unit Variable cost = US$ 1 085.5/t FB (Example 4.4)
Unit fixed cost = US$ 186.5/t FB (Example 4.4)
Daily Capacity = 2 t FB
Working days of the year = 270

Equation (7.21) and (7.22) are applied to calculate TR, TVC, TFC, TC and NPBT over the range from 0 to 100% capacity.

- Annual revenue = US\$ 1 560/t FB x Q (t FB/year) = 1 560 x US\$ Q/year
- Annual production cost =
  = US\$ 1 085.5/t FB x Q (t FB/year) + US\$ 186.5/t FB x 540 t FB/year =
  = US\$ (1 085.5 x Q + 100 710)/year

From Equation (7.24), the break-even point can be calculated as:

- N = 100 710/(1 560 - 1 085.5) = 210 t FB/year

Table 7.9 and Figure 7.6 show the variation of the different parameters.

Table 7.9

Revenue, Cost and Profit for Different Levels of Production for a Frozen Hake Plant

Percent utilization	Q (t/year)	TR (US\$ '000)	TVC (US\$ '000)	TFC (US\$ '000)	TC (US\$ '000)	NPBT (US\$ '000)
0	0	0	0	100.71	100.71	-100.71
20	108	168.48	117.23	100.71	217.94	- 49.46
40	216	336.96	234.47	100.71	335.18	1.78
60	324	505.44	351.70	100.71	452.41	53.03
80	432	673.92	468.94	100.71	569.65	104.27
100	540	842.40	586.17	100.71	686.88	155.52

Figure 7.6 illustrates the relationship between fixed cost and total cost and level of output, as well as income and level of output.

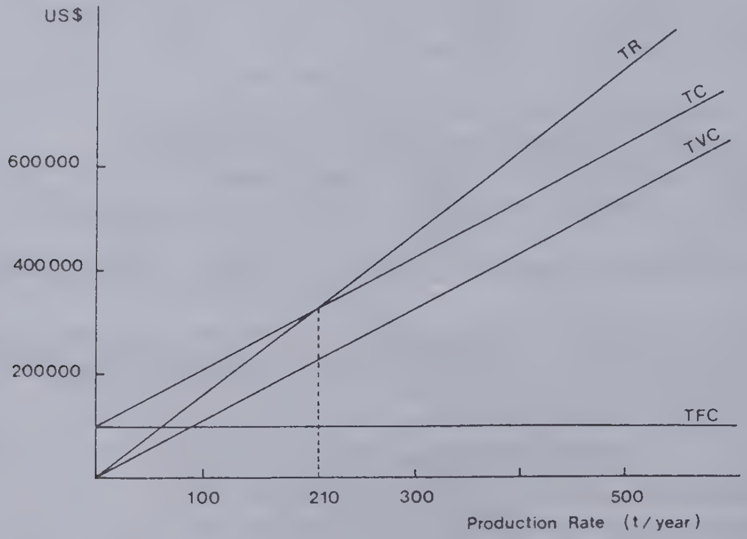


Figure 7.6 Graphical Representation of Break-even Point for a Frozen Hake Plant

For a linear break-even chart, profitable operation occurs to the right of the break-even point (39% of utilization of the plant or 210 t FB per year or 0.78 t FB per day). If production is lower, the operation will incur losses. If production is higher, earnings will be obtained.

Example 7.9 Determination of Break-even Point for a Fishmeal Plant

Analyse the break-even point for the fishmeal plant in Example 5.3, which processes 500 t of raw material daily.

Answer: Figure 7.7 shows the break-even point graph for the values given in Table 5.6, for the 500 t/day plant.

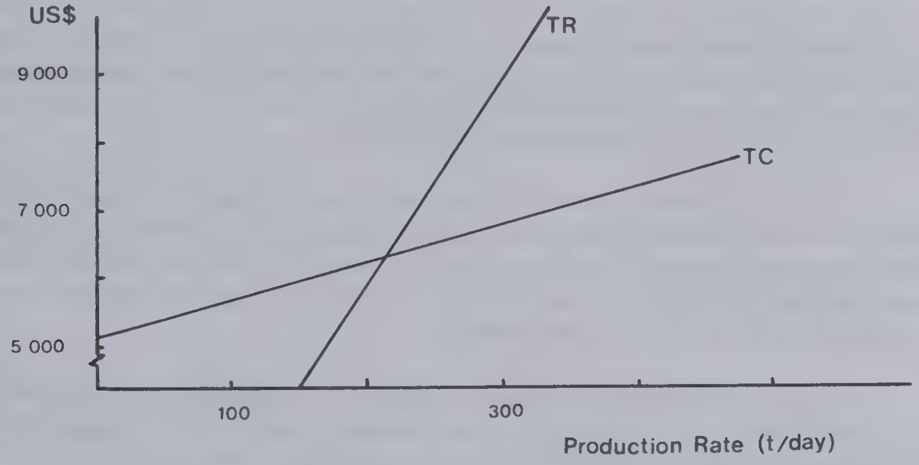


Figure 7.7 Break-even Point Graph for a 500 t of Raw Material per day Fishmeal Plant

7.7 Profitability of Artisanal Fisheries

In artisanal fisheries which exploit a great number of species, prices are frequently fixed by or for different species of equal size. These groups may or may not have similar biological characteristics. For the commercial species, the price is set in a manner directly proportional to the consumer's preference. Although they can change substantially during certain seasons, due to variations in the volume caught, variety of species and during cultural and religious events, these prices are generally stable. As a result, there is a difference in income received by each business in the course of any given year (Stevenson *et al.*, 1982).

To improve the economic balance, countries support small-scale fisheries with different methods of financing. For example, in Ghana and Senegal, the Government has implemented a system which focuses mainly on the reduction of duties on fuel which have been used by fishing vessels and canoes for more than 10 years. This policy of reducing operational costs has a favourable influence on motorization in both countries. In Ghana, prices have been reduced from US$ 0.80 to US$ 0.25 per litre, while in Senegal it is less than half the regular price of US$ 0.50 per litre.

At times this type of policy can result in distortions, as engines that are larger than necessary are bought, and movable rather than stationary winches are used which increase the operational costs of the sector and the economy in general (Greboval, 1989).

Another study conducted in Seychelles (Parker, 1989) showed that if economic difficulties are experienced by small fishing vessels, those craft between 8 and 13 m long also suffer, due to the greater quantity of capital invested in each fishing unit. For this reason, the economic yield of three units of this type of fishing vessel is analysed:

1. Standard model (with 27-37 hp engine)

2. Standard model with echo-sounder and electric reels (chosen because a better catch was obtained), 56 hp engine

3. Similar to second model, with equal capacity, but with 70 hp engine (11.6 m long)

Income from a single trip can be considered as a function of the prices, rate of capture attained by types of fishing gear used, composition of catch and duration of trip (limited to the capacity to maintain the vessel). In the first instance, the estimated income per trip is US$ 1 558 and for the others US$ 2 833.

The most important parameter, in relation to total income, is the number of trips that the boat can make in a given period of time. The operating and financial costs are met more easily if the boat is operated more intensively. However, lack of adequate maintenance will reduce the cash flows and a small cash flow will reduce the availability of funds for maintenance, thus creating a vicious circle.

The question is debatable of what is a reasonable rate of return for a boat-owner given that the bank's interest rate for the fisherman seeking a loan is 10% or more (although this could be acceptable for those accustomed to handling large amounts of capital).

It is difficult to administer an investment which only yields 14%, when 10% has to be paid for loans. Table 7.10 analyses the means of reversing the situation by eliminating a tax on fuel (Column 3), increasing the prices paid for catch by 10% (Column 4) and taking the two effects together (Column 5). For the standard vessel, an average 2-2.5 trips per month were estimated. For vessels 2 and 3, only the maximum number of trips were considered. For the vessels owners who wish to change to higher capacity engines (Vessel 3), it is almost impossible to meet loan repayments without increasing the sale price of the catch or reducing the operating costs (Parker, 1989).

Table 7.10

Rate of Return on the Original Investment (%) for Vessels 1,2 and 3

	Investment (US$)	Base	i_{ROI1}	i_{ROI2}	i_{ROI3}
Vessel 1	33 480	5.64	8.56	9.36	12.29
Vessel 1	33 480	11.79	15.54	16.44	20.10
Vessel 2	67 500	14.24	17.76	18.44	21.87
Vessel 3	72 540	9.3	13.30	14.27	18.26

Some results from trials carried out along the coasts of Karnataka (India) may be mentioned (Nordtheim *et al*., 1980). As part of the FAO programme to increase and improve the utilization of small pelagics, the use of refrigerated sea water (RSW) in the handling and transport of pelagic species was studied. The aim was to increase the use for human consumption, quality and storage time, and market value of these raw materials. US$ 53 424 was invested in adapting the holds to the use of RSW; the financial analysis yielded the following values for a 13.36 m long vessel with an average annual catch of 600 t:

Net present-worth	- US$ 25440 (i = 15%)
IRR	- 47%
Pay out time	- during the third year

A further example are some economic studies on boats fishing pelagic species, such as anchovy, that have been done in Peru. In order to determine the profitability, the present-worth method defined by Equation (7.12) was applied. A discount rate of 15% was considered, based on the interest rates of the loans received, and including administrative and commission costs. Figure 7.8 illustrates the variation in profitability according to size of the hold, for different rates of interest.

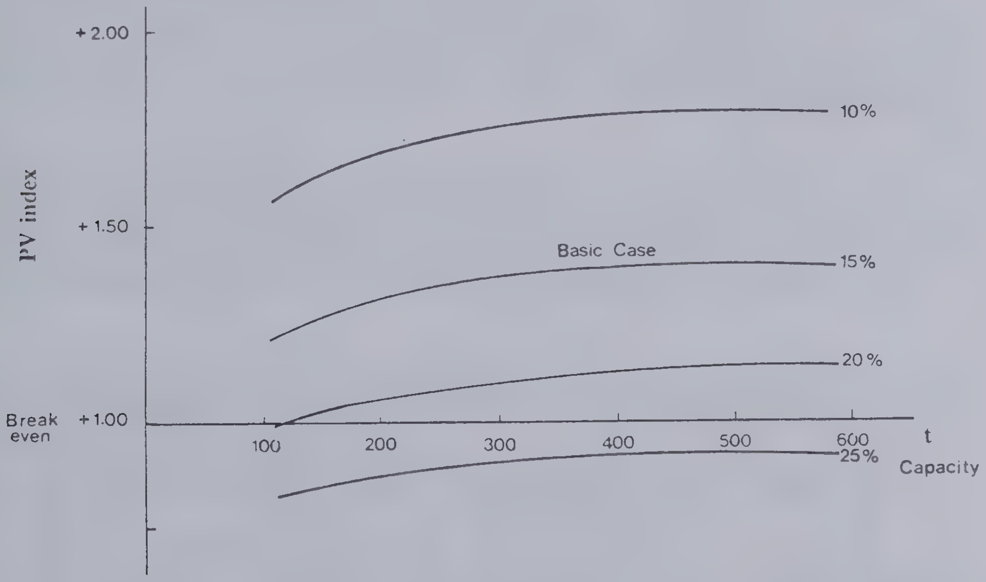


Figure 7.8 Influence of Change in Rate of Discount. Pelagic Fishing Boats in Peru, according to Engstrom *et. al* (1974)

At a rate of 20%, boats with less than 200 t capacity are not profitable, while no boat can realize profits if the rate rises to 25% (Engstrom *et al.*, 1974).

7.8 Profitability for Small and Medium Fish Plants

The following are different economic analyses for various small and medium sized fish plants. An economic analysis was made of small fish canning plants in tropical countries, for the production of 10 000 (model 1) and 20 000 (model 2) cans of 125 g of sardines every 8 hours. The substitution of machinery (model 1) for labour (model 3) was also evaluated at the same time.

Table 7.11 shows the values resulting from the application of the internal rate of return and present-worth methods, utilizing a discount rate of 10% for the last method, which is the rate adopted by the Tropical Products Institute in project evaluation. A useful life of 10 years was considered.

Table 7.11
Evaluation of Profitability for Small Fish Canning Plants

	Model 1	Model 2	Model 3
Present-worth (i = 10%) (US$)	1 262 100	2 678 910	1 153 382
Internal rate of return (r)	61.5%	69.5%	59.0%
A) 200 days/year	47.5%	54.0%	45.0%
150 days/year	33.5%	38.5%	31.5%
B) 50% to domestic market	33.5%	39.0%	29.5%
C) +25% Production costs	36.7%	42.6%	32.0%

A sensitivity analysis was also made using the following parameters: (A) reduction of working days per year (200 and 150); (B) 50% of the production is sold in the domestic market; (C) 25% increase in operating costs. The base model considered 250 days/year and 100% of production designated for export, where prices higher than those of the domestic market (60%) could be obtained.

The internal rate of return (r) decreases by an average 38.5%. If the first two parameters are considered together, the values found are lower by 50% and results are negative when the third factor is incorporated (Edwards *et al.*, 1981). Table 7.12 shows the investments required and the IRR for fish and shellfish canning plants in Indonesia (Bromiley *et al.*, 1973).

Table 7.12
Internal Rate of Return (r) for Fish Canning Plants in Indonesia

Location	Annual Capacity (in '000 cans)	Total Investment (US$)	r (%)
Bitung	10^4 (tuna)	1 850 000	36 (*)
Pare-Pare	720 (tuna)	360 000	35
Central Java	3 840 (shrimp)	810 000	45

(*) Calculation of the internal rate of return (r) is affected by the interest that must be paid by the investment; if half of the investment is financed by a 10 year loan with an 12% interest rate, the value of the internal rate of return would be 52%.

The internal rate of return calculated for mechanized canning plants in Norway, with a production capacity of 15 t/day of raw material (sardines), was 27.1% (Myrseth, 1985). There are evaluations where it is practical to express the results as a function of variables whose estimates are uncertain. For example, the economic performance of freezing plants for whole fish block was studied in order to calculate the price that should be paid for raw material, if favourable internal rates of return of 10 and 20% were considered, along with a useful life of 15 years for the investments. Table 7.13 summarizes the results.

Table 7.13
Price of Raw Material Calculated for Internal Rates of Return of 10 and 20%

	Raw Material Price (US$/t)	
	r = 10%	r = 20%
Annual Production: 2 240 t Investment: US$ 322 430 Product Selling Price = US$ 228/t	109	94
Annual Production: 3 360 t Investment: US$ 535 480 Product Selling Price = US$ 228/t	380	243

Two production levels were studied. In the first case, 2 240 t of whole fish were used annually, with two 8-hour shifts per day, working 250 days; in the second, 3 360 t were used, with an additional 8-hour shift and increased refrigeration and ice plant capacity. If the energy costs decrease by 50%, the purchase price of the raw material could rise by US$ 17/t. An internal rate of return for a hypothetical case involving a fishmeal plant, with an investment of US$ 10 000 (over a 5-year period) was calculated at 18.5% (FAO, 1986a). In small fish smoking plants, the distribution of profits is similar to that used by artisanal fishermen. The income received from the operations of the plant is shared equally among the workers in the plant, with one share for the "association", once operational costs have been deducted. As the plant functions with three workers, the income is divided into four parts; one for each worker and one for the Trade Union Association (FAO, 1986a).

In Sri Lanka, an evaluation was made of the production of liquid silage for a plant with an annual capacity of 450 t of product, at three different sales prices, taking a value of US$ 333/t and depreciation percentages of 20 and 25%. Determination of the internal rates of return for a useful life of 5 years resulted in values of 77, 38 and 26% respectively. These figures indicate that the project would be highly profitable (Aagaard *et al.*, 1980) (Disney & James, 1980).

Another economic analysis shows the production of liquid silage from shrimp by-catch in Mexico. The fixed investment rises to US$ 28 289 and the working capital to US$ 6 667 for an annual production of 312 t of silage. The production costs are US$ 92/t taking into account an amortization period of five years. The sales price was calculated using an internal rate of return of 15%. The price for silage showed significant advantages when compared to the prices of other sources of proteins and fishmeal. It should be added that the cost per unit of protein is profitable, even when species and inputs (acid) at higher prices are used in the production (Edwards and Disney, 1980). In general, it would appear that the production of liquid silage is profitable, but special consideration must be taken of the distance of the factory from the consumers and the competitive prices of other feeds. There is no question of the nutritional advantage of its use in the formulation of feed for pigs (Bertullo, 1989; Andrade *et al.*, 1992; Bello *et al.*, 1992), and the possibility of its utilization in animal feeds for birds, fur animals, cultured fish and calves.

It is useful to study the influence of profitability on each component of income, expenditure and investment, as a complement to profitability studies. This information will enable fundamental adjustments to be made to those parameters that show greatest influence, leaving the other parameters to a less ambitious estimate.

In a sensitivity analysis several variables with reasonable designs are selected, and are varied at successive stages, through an allowable percentage of variation. The resulting variations in the profitability indicate the importance of each variable investigated.

Example 7.10 Sensitivity Analysis

Make a sensitivity analysis for a canning plant, using the conditions for the basic case given in Table 7.14. The relative parameter is defined as the relationship between the real value of the parameter and its value in the example, calculating the relative change of the Internal Rate of Return in the same manner.

Table 7.14
Assumptions for the Basic Case

1	Production speed is equal to annual sales
2	Plant capacity: 100 000 (cans/day)
3	Working capital as empirical function of fixed investment, operating costs and sales
4	Depreciation by straight-line method
5	Estimated useful life: 10 years
6	Taxation rate: 45% (average value for Argentina)
7	Zero residual value
8	No financial costs
9	150 days/production year (average for canning plants in Argentina)
10	Selling price remains constant while other parameters vary

Answer:

Table 7.15 and Figure 7.9 show the results of the sensitivity analysis.

Small variations in the sales price and costs of raw material (fish and packaging) modify the profitability of the plant to a considerable extent. This would indicate that for a quick estimate of costs and profitability, these data be known exactly, even when precise data are not available on plant capacity, labour, utilities and fixed costs. Raw material requirements must be calculated as precisely as possible and an accurate market study undertaken to determine the sales price. This is particularly true for processes that are not capital-intensive, that is, those processes that are controlled by variable costs. Here, the effect of sale price on profitability is approximately double that of the other parameters (Cerbini and Zugarramurdi, 1981a).

Table 7.15
Sensitivity Analysis

Number in Figure 7.5	Parameter	Variation in Parameter	Relative Value of Internal Rate of Return
1	Selling Price	+ 10	1.90
		- 4	0.57
2	Rate of Production	+ 20	1.14
		- 20	0.88
3	Raw Material Price	+ 15	0.58
		- 15	1.35
4	Price of Can	+ 15	0.28
		- 15	1.56
5	Investment	+ 20	0.64
		- 20	1.20
6	Days per year	+ 47	1.29
		- 25	0.83
7	Costs of Labour	+ 20	0.63
		- 20	1.31

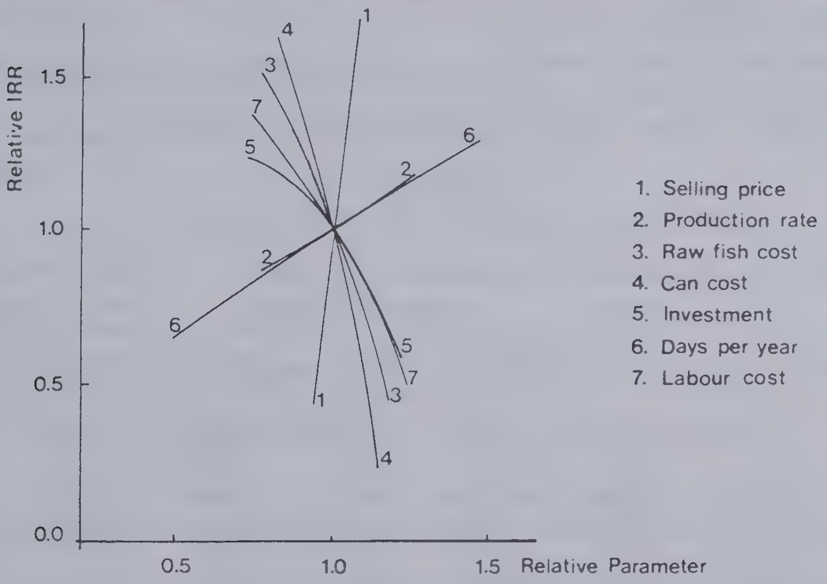


Figure 7.9 Sensitivity Analysis for Canned Anchovy, Argentina 1981

7.9. Inflation in Profitability Calculation

Inflation is an economic phenomenon feared worldwide; developed countries monitor it closely and the anticipated and actual inflation are in the news at least once a month. In many developing countries inflation effects are often endured. Inflation can be due to a number of reasons, usually linked to macro-economics decisions and politics, such as emission of currency without the proper support. Additional information on the concept of inflation is given in Appendix B.5. Table 7.16 shows series of inflation rates in several Latin American countries where a permanent occurrence of high values (2 and 3 digits) are observed. Inflation indicators are based on particular mixtures of goods and services chosen to represent the material needs of an average citizen.

Table 7.16
Consumer Price Index (average increase % per year)

Year	Argentina	Bolivia	Brazil	Colombia	Chile	Mexico	Uruguay
1976	444.1	4.5	35.7	17.4	211.8	15.8	50.6
1977	176.0	8.1	40.5	28.6	91.9	28.9	58.1
1978	175.5	10.4	38.3	18.7	40.1	17.5	44.5
1979	159.5	19.7	50.2	24.2	33.4	18.2	66.8
1980	100.8	47.2	77.9	27.9	35.1	26.3	63.5
1981	104.5	32.2	95.6	29.4	19.7	28.0	34.1
1982	164.8	92.0	89.6	23.4	9.9	58.9	19.9

Source: (Index Económico, 1984); (Coyuntura y Desarrollo, 1983)

Given the wide calculating basis, these indexes represent a reasonable estimate of the inflation rate for other economic activities. Such inflation is termed "general" where, it is assumed, all economic sectors increase their prices at the same rate, contrary to so-called "repressed" or "differential" inflation, where, for several causes such as technological changes, shortages of a few raw materials, government policies, etc., the different factors of the economy may inflate at unequal rates. In countries with extreme inflation rates, the "differential" deviations become less important and may be ignored. This can be observed in Table 7.17 which presents a series of inflation indexes for Argentina.

Table 7.17
Price Evolution Indicators in Argentina (1970 base = 1)

Consumer Price	Index	General Index	Construction Cost Index			Wholesale Price Index	Agricultural Price Index
			Materials	Labour	General Expenses		
1970	1.00	1.00	1.00	1.00	1.00	1.00	1.00
1971	1.391	1.432	1.419	1.457	1.357	1.482	1.602
1972	2.284	2.268	2.393	2.158	2.253	2.608	3.002
1973	3.283	3.659	3.623	3.742	3.426	3.41	3.506
1974	4.598	5.98	6.343	5.816	5.283	4.642	4.259
1975	20.006	28.604	36.923	21.514	26.892	20.807	16.923
1976	89.536	91.00	136.27	50.836	88.822	101.18	94.593
1977	233.18	204.63	330.48	96.67	191.032	250.07	218.08
1978	629.22	517.14	810.69	262.81	475.89	608.43	557.60
1979	1 508.46	1 251.50	2 036.11	567.61	1 159.61	1 392.45	1 203.12
1980	2 830.40	2 527.30	3 905.96	1 300.63	2 481.07	2 192.57	1 637.98
1981	6 545.96	5 247.30	8 320.66	2 611.65	4 768.25	6 143.51	5 123.00
1982	20 276.10	19 322.70	31 635.40	9 167.80	15 881.40	25 268.50	21 209.50
1983	108 208.90	127 361.00	181 936.00	79 248.90	104 299.00	129 013.00	103 829.60
β	93.50	93.50	100.90	83.30	91.60	94.30	91.80

β : Average Inflation Index (by least-squares)

Even in this period of intense social and economic change, indicated in Table 7.17 the differences between various sectors did not exceed 10% as can be observed in the last row ß of Table 7.17.

Although it seems that most countries, including developing countries, are now (1995) moving towards a more stable (and less inflationary condition), fish processing companies operate in the real world, and therefore they may have to strive to survive under inflation conditions. Inflation affects calculations of profitability of investment projects, causing the analysis and the decision-making to become difficult and confused. This is especially true in countries where high inflation rates are virtually constant, as was the case of Argentina and other Latin American countries.

This section will deal exclusively with the influence of general inflation on the profitability analysis of a project, showing the difference between real profit and that which can only be qualified as a numerical result product of an inflationary process.

The use of stable currency for cash flow values is a usual procedure to find values of "real internal rate of return". However, in considering components of cash flow which are independent of the inflation rate, such as amortization of loans and the real value of working capital, the application of cash flow values in stable currency for the calculation of a real IRR is not valid and the formulas described must be modified (de Santiago *et al.*, 1987).

The effect of the consideration of inflation on the Present-Worth and Internal Rate of Return Methods are first analysed by applying them to the example of the freezing plant.

7.9.1 Effect of inflation on the present-worth (PW)

Equation (7.11) is valid for the case of zero inflation. In the case where inflation has a fractionary rate β, this equation can be written as:

$$PW = \sum_{j=1}^{n} \frac{CF_j}{(1 + i_R)^j (1 + \beta)^j} \times I_T \qquad (7.25)$$

When $\beta = 0$, the equation (7.25) is the same as (7.11) with i_R (real rate) $= i$

Example 7.11 Calculate the Present-Worth (PW) (taking inflation into consideration)

Calculate the Present-Worth (PW) for the hake freezing plant in Example 7.1. Use an annual inflation rate of 80%, assuming that the plant is located in Argentina.

Answer: The exchange rate is 10 000 Australes/US$ 1 (1990). Therefore, if Table 7.1 is expressed in Australes, the values will be those shown in Table 7.18.

Applying Equation (7.11), the present-worth of the project at the end of year 10 is 1 102 million Australes.

$$\sum_{j=1}^{10} \frac{CF_j}{(1+i_R)^j} = \frac{1.37\text{x}10^9}{(1.15)^1} + \frac{1.53\text{x}10^9}{(1.15)^2} + \ldots + \frac{1.53\text{x}10^9}{(1.15)^9} + \frac{(1.53 + 0.6)\text{x}10^9}{(1.15)^{10}} = 7.702 \text{ x } 10^9$$

$$PW = (7.702 - 6.60) \text{ x } 10^9 = 1.102 \text{ x } 10^9, \text{ so: } PW = 1\ 102 \text{ million Australes}$$

Table 7.18
Statement of Sources and Application of Funds for a Fish Plant when there is no Inflation (in '000 million Australes (A))

Activity	90	91	92	93	94	95	96	97	98	99
SOURCE										
Own capital	4.8									
Bank credit (*)	1.8									
Net Sales from activity	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	
8.42										
Total (a)	15.02	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42	8.42
APPLICATIONS										
Fixed Investment	6.0									
Working Capital	0.6									
Cost of Financing (**)	0.27									
Cost of Production	6.87	6.87	6.87	6.87	6.87	6.87	6.87	6.87	6.87	6.87
Total (b)	13.74	6.87	6.87	6.87	6.87	6.81	6.87	6.87	6.87	6.87
(a) - (b)	1.29	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56	1.56
Net Profit (***)	0.77	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Plus depreciation	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Cash Flow	1.37	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53

(*) 30% I_F = A 1 800 million (**) 15% Annual Rate (***) Deducting taxes on earnings (40%)

The example could be modified using an 80% annual inflation rate, but disregarding the effect of inflation and incorrectly applying Equation 7.11. The data for this situation are given in Table 7.19, and results in a present-worth of 221 800 million Australes.

Table 7.19
Statement of Sources and Applications of Funds for a Fish Plant with Inflation ($\beta = 0.8$) (in '000 million Australes (A))

Activity	90	91	92	93	94	95	96	97	98	99
SOURCE										
Own capital	4.8									
Bank credit (*)	1.8									
Net Sales from activity	15.2	27.3	49.1	88.4	159.2	286.5	515.7	928.3	1671.0	3007.8
Total (a)	21.8	27.3	49.1	88.4	159.2	286.5	515.7	928.3	1671.0	3007.8
APPLICATIONS										
Fixed Investment	6.0									
Working Capital	0.6									
Cost of Financing (**)	0.5									
Cost of Production	12.4	22.3	40.1	72.1	129.8	233.6	420.5	756.9	1362.5	2452.5
Total (b)	19.4	22.3	40.1	72.1	129.8	233.6	420.5	756.9	1362.5	2452.5
(a) - (b)	2.3	5.0	9.1	16.3	29.4	52.9	95.2	171.4	308.5	555.3
Net Profit (***)	1.4	3.0	5.4	9.8	17.6	31.7	57.1	102.8	185.1	333.2
Plus amortization	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Cash Flow	2.0	3.6	6.0	10.4	18.2	32.3	57.7	103.4	185.7	333.8

(*) 30% I_F = A 1 800 million (**) 15% Annual Rate (***) Deducting taxes on earnings (40%)

$$\frac{2.0\text{x}10^9}{(1.15)^1} + \frac{3.6\text{x}10^9}{(1.15)^2} + \frac{6.0\text{x}10^9}{(1.15)^3} + \frac{10.4\text{x}10^9}{(1.15)^4} + \frac{18.2\text{x}10^9}{(1.15)^5} + \frac{32.3\text{x}10^9}{(1.15)^6} + \frac{57.7\text{x}10^9}{(1.15)^7} +$$

$$+ \frac{103.4\text{x}10^9}{(1.15)^8} + \frac{185.7\text{x}10^9}{(1.15)^9} + \frac{(333.8 + 214.2)\text{x}10^9}{(1.15)^{10}} = 281.2 \text{ x } 10^9$$

PW = (281.2 - 6.60) x 10^9 = 274.6 x 10^9, so: PW = 274 600 million Australes

Taking inflation into account and correctly applying Equation (7.25) yields a totally different result, and reveals that the project actually has a negative PW.

$$\frac{2.0\text{x}10^9}{(1.15)^1\,(1.8)^1} + \frac{3.6\text{x}10^9}{(1.15)^2\,(1.8)^2} + \frac{6.0\text{x}10^9}{(1.15)^3\,(1.8)^3} + \frac{10.4\text{x}10^9}{(1.15)^4\,(1.8)^4} +$$

$$+ \frac{18.2\text{x}10^9}{(1.15)^5\,(1.8)^5} + \frac{32.3\text{x}10^9}{(1.15)^6\,(1.8)^6} + \frac{57.7\text{x}10^9}{(1.15)^7\,(1.8)^7} + \frac{103.4\text{x}10^9}{(1.15)^8\,(1.8)^8} +$$

$$+ \frac{185.7\text{x}10^9}{(1.15)^9\,(1.8)^9} + \frac{(333.8 + 214.2)\text{x}10^9}{(1.15)^{10}\;(1.8)^{10}} = 5.251 \text{ x } 10^9$$

PW = (5.251 - 6.60) x 10^9 = -1.349 x 10^9, so: PW = -1 349 million Australes

This example shows that the effect of inflation is to make a project appears more profitable than it really is. This could be the case of many past investment failures in developing countries.

Inflation affects the calculation of profitability of investment projects, making analysis and decision-making difficult, especially in those countries where high levels of inflation predominate. In turn, it negatively affects investment possibilities.

7.9.2 Effect of inflation on the IRR. Real Internal Rate of Return

The well-known concept of real rate of interest (Riggs, 1977; Barish and Kaplan, 1978) will be used which, is based on the following reasoning: Consider a trust I_o which for a year has yielded an interest (I_o x i); then the total amount I_1 will be:

$$I_1 = I_o \text{x} (1 + i) \tag{7.26}$$

If in this period there was an inflation rate β, the relationship between the real value of I_1 (designated I_{1o}) and the value of I_o would be:

$$I_{1o} = I_1 / (1 + \beta) = I_o \text{x} (1 + i)/(1 + \beta) \tag{7.27}$$

A real rate of interest i_R (taking into account the effect of inflation) (Jelen and Black, 1983; Jones, 1982) could be defined by the expression:

$$I_{1o} = I_o \times (1 + i_R) \tag{7.28}$$

Equating the expressions Equation (7.27) and (7.28), the following can be deduced:

$$i_R = \frac{(1 + i)}{(1 + \beta)} - 1 = \frac{(i - \beta)}{(1 + \beta)} \tag{7.29}$$

This formula differs from that commonly used:

$$i_{R\sim}\text{(real approximate rate of return)} = i - \beta \tag{7.30}$$

which is only valid when $\beta << 1$, (Holland and Watson, 1977; Estes *et al.*, 1980; Shashua and Goldschmidt, 1985). It gives an estimate of the real rate of interest higher than those defined by Equation (7.29). Having defined the relative error (ϵ) by Equation (7.31), it was found to coincide with the inflation rate:

$$\epsilon = \frac{i_{R\sim} - i_R}{i_R} = \frac{(i - \beta) - (i - \beta)/(1 + \beta)}{(i - \beta)/(1 + \beta)} = \beta \tag{7.31}$$

Introducing the concept of real rate of interest, defined by Equation (7.29), a real internal rate of return is determined when Equation (7.32), referring to discounted cash flow, is equal to zero:

$$DCF = \sum_{j=1}^{n} \frac{CF_j}{(1 + \beta)^j (1 + i_R)^j} - I_T = 0 \tag{7.32}$$

where CF_j is the net cash flow in year j and n is the number of periods in the project life. If the economy is affected by a phenomenon of general inflation the numerator of each term of the sum is assumed to have been expanded by the inflation rate:

$$CF_j = CF_{jo} (1 + \beta)^j \tag{7.33}$$

When adding Equation (7.33) to (7.32), it can be observed that the utilization of cash flow in constant value terms leads to the values of "real internal rate of return" (IRR).

Example 7.12 Calculation of Internal Rate of Return, IRR (r)

Calculate the internal rate of return for the hake freezing plant of Example 7.1. Use an 80% rate of annual inflation.

Answer:

From Table 7.19, a value of r = 96.9% is obtained. Calculating the IRR from the Net Cash Flow corrected by inflation, an i_R of 11% is obtained. From Equation (7.29):

$$i_R = \left(\frac{1 + 0.969}{1 + 0.8}\right) - 1 = 0.094$$

This result shows once again the effect of inflation on a case that appeared profitable, when inflation is not taken into account. However, in practice, several components of cash flow can be independent of the inflation rate, such as: amortization of loans, payments of interest, payment of taxes, adjustments to working capital, etc.; thus preventing the use of cash flow in constant currency for the calculation of a real IRR.

To face the inflation problem, some of these concepts will be analysed in a simple cash flow consisting of an initial investment yielding a constant cash flow when the inflation rate is zero during a planning horizon of 10 years.

7.9.3 Effect of the adjustment of working capital on the IRR

The inflation obliges to increase the working capital I_W. To study the effect of this increment on the profitability, it is assumed that the working capital may be expressed in fractions (f_{IW}) on the annual sales "S". Taking into account that the annual sales (S) and the annual operating costs (C) are expanded by the inflation:

$$CF_j = S_j - C_j = S_o \times (1 + \beta)^j - C_o \times (1 + \beta)^j \tag{7.34}$$

but there could be the need of an annual increase of working capital by:

$$\Delta I_{Wj} = f_{IW} \times S_{j-1} \times (1 + \beta) - f_{IW} \times S_{j-1} = f_{IW} \times S_{j-1} \times \beta \tag{7.35}$$

and the capital accumulated would be recovered at the end of the year N

$$I_{WN} = f_{IW} \times S_N \tag{7.36}$$

As a result, the IRR formula (before taxes) is transformed into:

$$0 = -(I_o + f_{IW} \times S_o) + \sum_{j=1}^{N} \frac{(S_o - C_o) \times (1+\beta)^j - f_{IW} \times S_o \times (1+\beta)^{j-1} \times \beta}{(1+\beta)^j \times (1+i_R)^j} + \frac{f_{IW} \times S_o \times (1+\beta)^N}{(1+\beta)^N \times (1+i_R)^N} \tag{7.37}$$

and with little change:

$$0 = -(I_o + f_{IW} \times S_o) + \frac{f_{IW} \times S_o}{(1+i_R)^N} + \frac{(1+i_R)^N - 1}{i_R \times (1+i_R)^N} \times \left(S_o - C_o - f_{IW} \times S_o \times \frac{\beta}{1 + \beta}\right) \tag{7.38}$$

and the following equation is derived:

$$\sum_{j=1}^{N} (1+i_R)^{-j} = \frac{(1+i_R)^N - 1}{i_R \times (1+i_R)^N} = F(i_R, N) \tag{7.39}$$

The effect of the inflation on the real profitability i_R by the devaluation of the working capital is expressed by Equation (7.38). To analyse such influence the following dimensionless relationships are substituted in Equation (7.38):

$$R = S_o/C_o \qquad \text{and} \qquad X = C_o/I_o$$

and the whole equation is divided by I_o , thus giving the final expression:

$$0= -1 - X \times R \times f_{IW} \times \{1 - \frac{1}{(1+i_R)^N}\} + \frac{(1+i_R)^N - 1}{i_R \times (1+i_R)^N} \times \{X \times (R-1) - X \times R \times f_{IW} \times \frac{\beta}{1 + \beta}\} \qquad (7.40)$$

A panorama of the inflation showing the different parameters that includes Equation (7.40) is illustrated in Table 7.20.

Table 7.20

Real Internal Rate of Return

GP^*	I_W^*	β=0	0.2	0.5	1.0	1.5	2.0	4.0
0.3	0.1	0.2447	0.2269	0.2089	0.1906	0.1794	0.1719	0.1567
	0.3	0.2013	0.1554	0.1072	0.0559	0.0230	---	---
	0.5	0.1703	0.1033	0.0310	---	---	---	---
	0.7	0.1471	0.0641	---	---	---	---	---
0.5	0.1	0.4440	0.4280	0.4120	0.3958	0.3861	0.3795	0.3665
	0.3	0.3720	0.3306	0.2886	0.2456	0.2192	0.2013	0.1648
	0.5	0.3191	0.2586	0.1960	0.1306	0.0893	0.0607	0.00002
	0.7	0.2788	0.2032	0.1240	0.0390	---	---	---
0.7	0.1	0.6320	0.6166	0.6011	0.5855	0.5762	0.5700	0.5575
	0.3	0.5326	0.4930	0.4530	0.4127	0.3883	0.3720	0.3390
	0.5	0.4595	0.4016	0.3429	0.2830	0.2462	0.2213	0.1703
	0.7	0.4035	0.3313	0.2575	0.1810	0.1333	0.1004	0.0314

Note:

$$GP^* = X \times (R-1) = \frac{S_o - C_o}{I_o} \quad ; \quad I_W^* = X \times R \times f_{IW} = \frac{I_W}{I_o} \quad ; \quad N = 10$$

Table 7.20 shows that the real rate of return is deteriorated by inflation. This reduction becomes more pronounced as the working capital acquires more relative importance. In order to maintain the profitability of a company, the immediate action of managers should be to increase the selling price of the products in relation to the costs, assuming that this could be possible without reducing the sales volume.

This strategy is represented by Equation (7.41) by R' > R. In order to maintain the constant i_R resulting in Equation (7.41), the proportional increase (R'/R) can be obtained by Equation (7.40) with β=0 and the value of the original R.

$$\frac{R'}{R} = \frac{(1/\ i_R) - f_{IW}}{(1/i_R) - f_{IW} \times \{1 + [\beta/(1+\beta) \times i_R]\}} \qquad (7.41)$$

For a "before-tax profitability" $i_R = 0.3$, values from Equation (7.41) are shown in Figure 7.10. It can be observed from Figure 7.10 that the appropriate factor can reach high values, and when there is an increase in prices producing a multiplying effect over inflation indexes.

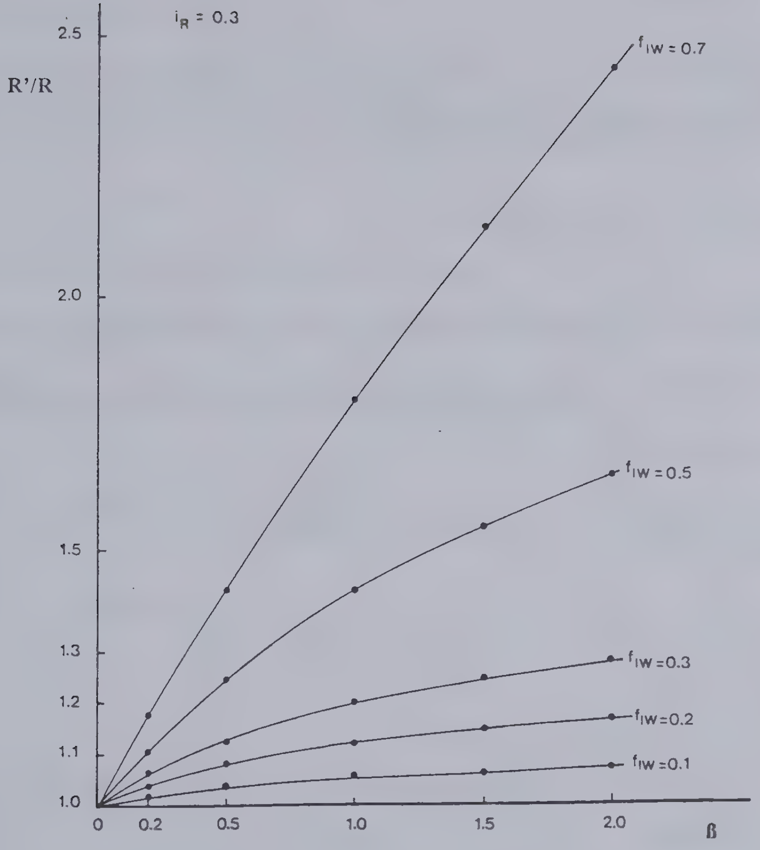


Figure 7.10 Selling Price Increasing Ratio (R'/R) vs Inflation Rate (ß) at Different Percentages of Working Capital, a Constant Profitability $i_R = 0.3$ is Considered

7.9.4 Inflation relationships in continuous form

An analysis using a continuous formula is appropriate in the case of the working capital devaluations, due to high rates of inflation, so the adjustments must be made in shorter time periods. For continuous interest, simple deductions yield the following relationships:

Future value: $F(t) = F(o) \times \exp(i \times t)$ (7.42)
Future value in constant currency: $F_o(t) = F(o) \times \exp(i \times t) \times \exp(-\beta \times t)$ (7.43)

Definition of real rate of interest: $F_o(t) = F(o) \times \exp(i_R \times t)$ (7.44)

It is important to note that in the continuous case the approximate Equation (7.30) is valid. The resulting equation for calculating the IRR without inflation is given by:

$$0 = -(I_o + f_{IW} \times S) + \int_0^{t_n} (S-C) \times \exp(-i \times t)\, dt + f_{IW} \times S \times \exp(-i \times t_n) =$$
$$= - I_o + \{[(S-C)/i] - (f_{IW} \times S)\} \times \{1 - \exp(-i \times t_n)\} \quad (7.45)$$

where the i that makes zero the equality in Equation (7.45) is the internal rate of return (IRR). When inflation is taken into account, the following definitions will be used:

$$S = S_o \times \exp(\beta \times t) \tag{7.46}$$

$$C = C_o \times \exp(\beta \times t) \tag{7.47}$$

$$I_W = f_{IW} \times S = f_{IW} \times S_o \times \exp(\beta \times t) \tag{7.48}$$

$$\frac{dI_W}{dt} = f_{IW} \times S_o \times \beta \times \exp(\beta \times t) \tag{7.49}$$

With those expressions, the equation that defines the real internal rate of return will be:

$$0 = -(I_o + f_{IW} \times S_o) + \int_0^{t_n} (S_o - C_o) \times \exp[(\beta - i) \times t]dt + \int_0^{t_n} f_{IW} \times So \times \beta \times \exp[(\beta - i) \times t]dt + + f_{IW} \times S_o \times \exp[(\beta - i) \times t_n] \tag{7.50}$$

Introducing the concept of real rate of interest (continuous case $i_R = i - \beta$), the integrated equation is:

$$0 = -I_o + \left[\frac{S_o - C_o}{i_R} - f_{IW} \times S_o \times \left(1 + \frac{\beta}{i_R}\right)\right] \times [1 - \exp(-i_R \times t_n)] \tag{7.51}$$

Using the relationships X and R, and dividing by I_o, the Equation (7.51) is transformed into (7.52), that is the continuous expression equivalent to Equation (7.40).

$$0 = -1 + \left[\frac{X \times (R-1)}{i_R} - X \times R \times f_{IW} \left(1 + \frac{\beta}{i_R}\right)\right] \times [1 - \exp(-i_R \times t_n)] \tag{7.52}$$

and the continuous expression of (R'/R) corresponding to (7.41):

$$\frac{R'}{R} = \frac{(1/i_R) - f_{IW}}{(1/i_R) - f_{IW} \times [1 + (\beta/i_R)]} \tag{7.53}$$

The "continuous" Equations (7.52) and (7.53) show an unfavourable effect compared with their similar annual discrete forms and this is more noticeable as the inflation rate increases. Continuous equations show that in a profitability analysis the study with annual period can lead to serious mistakes. For certain inflation rates, analysis of Equation (7.53) shows that for high f_{IW} values of R'/R allowing a reasonable profitability would not be possible. In consequence, the enterprises must decrease their working capital and accept lower profitability. The persistence of the inflation phenomenon would lead to capital losses.

7.9.5 Effect of financing of working capital on the IRR

Some sectors of the economy have no possibility of modifying the selling price of their products, such as in the case of exporting industries or in open economies with perfect competition from foreign countries. In such instances, another available resource is the utilization of loans which can improve or deteriorate the project profitability according to the stipulated rate of interest. Furthermore, the amount of the investment made by the firm is reduced, changing also the IRR.

There is a large variety of loan types, therefore only those which permit some generalizations will be analysed. First, the financing of the working capital year by year will be analysed; that is, a loan must be totally amortized in a period j

$$f_{IW} \text{ x } S_o \text{ x } (1 + \beta)^{j-1}$$

paying a rate of interest i_p and taking out a new loan:

$$f_{IW} \text{ x } S_o \text{ x } (1 + \beta)^{j}$$

In this case the equation that defines the IRR is as follows:

$$0 = -I_o + F(i_R,N) \text{ x } [S_o - C_o - \frac{f_{IW} \text{ x } S_o \text{ x } i_p}{1 + \beta}] \qquad (7.54)$$

or with the dimensionless relationship:

$$0 = -1 + F(i_R,N) \text{ x } [X \text{ x } (R-1) - X \text{ x } R \text{ x } f_{IW} \text{ x } \frac{i_p}{1 + \beta}] \qquad (7.55)$$

Equation (7.55) is obtained from Equation (7.40) using $\beta = 0$, and it shows the maximum rate of interest i_p that would be paid for financing the working capital while keeping a constant profitability equal to the zero inflation case.

$$i_p = i_R \text{ x } (1 + \beta) \qquad (7.56)$$

For some cases studied in Table 7.20, figures of i_p calculated from Equation (7.56) are presented in Table 7.21. If a constant profitability is desired, an interest rate higher than inflation could only be paid at low inflation rates. At higher inflation rates, lower interest rates (including negatives) must be paid. Even though it is useless to maintain the level of profitability, the financing of the working capital by loans at an interest rate lower than total project profitability (including inflation), would yield a net improvement on the real profitability, but the loss from inflation does not suffice when the values given from Equation (7.56) do not reach that project profitability.

Table 7.21
Rates of interest (i_p) for Financing Working Capital at Constant Profitability

GP^*	I_W^*	$i_R=0$	$\beta=0.2$	0.5	1.0	1.5	2.0
0.3	0.7	0.1471	0.1765	0.2206	0.2942	0.3677	0.4413
	0.5	0.1703	0.2043	0.2554	0.3406	0.4257	0.5109
	0.3	0.2013	0.2418	0.3019	0.4026	0.5032	0.6039
	0.1	0.2447	0.2436	0.3670	0.4894	0.6117	0.7341
0.5	0.7	0.2788	0.3345	0.4182	0.5576	0.6970	0.8364
	0.5	0.3191	0.3829	0.4786	0.6382	0.7977	0.9573
	0.3	0.3720	0.4464	0.5580	0.7440	0.9300	1.1160
	0.1	0.4440	0.5328	0.6660	0.8880	1.1100	1.3320

From the cases presented in Table 7.20, real profitability that could be reached by financing the working capital at rate of interest $i_P = \beta$ (neutral real rates of interest) are shown in Table 7.22, observing important improvements with respect to those values given in Table 7.20.

Table 7.22

Rate of Profitability with Financing of Working Capital with Neutral Rates

GP^*	I_W^*	$\beta=0.2$	0.5	1.0	1.5	2.0	4.0
0.3	0.1	0.2538	0.2341	0.2141	0.2018	0.1936	0.1768
	0.3	0.2141	0.1510	0.0814	0.0346	—	---
	0.5	0.1726	0.0560	---	---	---	---
	0.7	0.1287	---	---	—	---	---
0.5	0.1	0.4733	0.4558	0.4381	0.4275	0.4204	0.4061
	0.3	0.4381	0.3845	0.3298	0.2961	0.2732	0.2262
	0.5	0.4025	0.3111	0.2141	0.1510	0.1056	0.0000
	0.7	0.3664	0.2341	0.0814	---	---	---
0.7	0.1	0.6795	0.6625	0.6455	0.6353	0.6285	0.6148
	0.3	0.6455	0.5943	0.5428	0.5117	0.4908	0.4487
	0.5	0.6114	0.5255	0.4381	0.3845	0.3482	0.2732
	0.7	0.5772	0.4557	0.3298	0.2499	0.1936	0.0064

7.9.6 Effect of loans on the investment on the IRR

The utilization of a loan financing a percentage of total investment amortized in equal shares at constant currency (a loan with indexed payments) will be analysed. It is assumed that amortization of the loan will be in N payments, where:

N = economic life of the project

Amount of the loan $p \times I_o$; $0 < p < 1$

Amortization: $A_j = p \times I_o \times F_P(i_P,N) \times (1+\beta)^j$

$$F_P = \frac{i_P \times (1+i_P)^N}{(1+i_P)^N - 1}$$

i.e., the annuity factor. It follows that the real internal rate of return is the root of the following dimensionless equation:

$$0 = -(1-p) - X \times R \times f_{IW} \times [1-(1+i_R)^{-N}] + F(i_R,N) \times [X \times (R-1) - X \times R \times f_{IW} \frac{\beta}{1+\beta} - p \times F_P(i_p,N)] \qquad (7.57)$$

The stipulated interest is equivalent to the real internal rate of return of an equivalent investment to the amount borrowed. Then, it is obvious that if the $i_P < i_R$, where i_R is the project profitability without the loan from a borrower's viewpoint, the profitability would improve. Nevertheless, as the inflation increases and the profitability decreases below the interest rate of the loan, the latter can be made highly onerous. A contrary effect is observed for $i_R < 0.1$ in the result presented in Table 7.23, where $i_{R'}$ is the project profitability with a loan at an interest rate $i_P = 0.1$.

Table 7.23
Variation of the Real Rate of Return vs
Inflation Rate for Indexed Loans on Investment

p = 0.7	$\beta = 0$	0.2	0.5	1.0	1.5	2.0	4.0
Case 1							
$GP^* = 0.3$	$i_R = 0.2013$	0.1554	0.1072	0.0559	0.0230	---	---
$I_W^* = 0.3$	$i_{R'} = 0.2983$	0.2083	0.1142	0.0130	-0.0530	---	---
Case 2							
$GP^* = 0.5$	$i_R = 0.3191$	0.2586	0.1960	0.1306	0.0893	0.0607	0.00002
$I_W^* = 0.5$	$i_{R'} = 0.4789$	0.3723	0.2637	0.1518	0.0820	0.0338	-0.06780
Case 3							
$GP^* = 0.7$	$i_R = 0.4035$	0.3313	0.2575	0.1810	0.1333	0.1004	0.0314
$I_W^* = 0.7$	$i_{R'} = 0.5843$	0.4663	0.3472	0.2259	0.1514	0.1006	-0.0045

Rate of interest of the loan $i_P = 0.1$

7.9.7 Effect of the non-indexed loans on the investment on the IRR

To improve profitability, the interest rate of a loan must be less than the total internal rate of return (including the real rate plus the inflation rate), irrespective of whatever amortization scheme is applied. This conclusion can be deduced from a study on the following dimensionless equation:

$$0 = -(1-p) - X \times R \times f_{IW}\left[1-(1+i_R)^{-N}\right] + F(i_R,N) \times \left[X \times (R-1) - X \times R \times f_{IW} \times \frac{\beta}{1+\beta}\right] - \frac{(1+i_R)^N \times (1+\beta)^N - 1}{(i_R+\beta+i_R \times \beta) \times (1+i_R)^N \times (1+\beta)^N} \times p \times F_P(i_P,N) \qquad (7.58)$$

where it has been considered:

Amount of loan $p \times I_o$ $\quad 0 < p < 1$
Amortization: $A_j = p \times I_o \times F_P(i_P,N)$

The fact that $i_{R'} > i_R$ when it is $i > i_p$ is shown in Table 7.24. This type of loan would have little difficulty to face possible increases in the inflation rate.

Table 7.24
Variation of the Internal Rate of Return vs Inflation Rate for Non-Indexed Loans
Rate of Interest of the Loan $i_P = 0.72$; Financed Investment Fraction $p = 0.70$

	$\beta=0$	0.2	0.5	1.0	1.5	2.0	4.0
Case 1	$i_R = 0.2013$	0.1554	0.1072	0.0559	0.0230	.—	.—
$GP^* = 0.3$	$i = 0.2013$	0.3865	0.6608	1.1118	1.5575	.—	.—
$I_W^* = 0.3$	$i_{R'} =$.—	0.01009	0.0938	0.1037	0.0908	.—	.—
Case 2	$i_R = 0.3191$	0.2586	0.1960	0.1306	0.0893	0.0607	0.00002
$GP^* = 0.5$	$i = 0.3191$	0.5103	0.7940	1.2612	1.7232	2.1821	4.0001
$I_W^* = 0.5$	$i_{R'} = 0.0557$	0.1774	0.2115	0.1914	0.1632	0.1388	0.07755
Case 3	$i_R = 0.4035$	0.3313	0.2575	0.1810	0.1333	0.1004	0.0314
$GP^* = 0.7$	$i = 0.4035$	0.5976	0.8862	1.3620	1.8332	2.3012	4.157
$I_W^* = 0.7$	$i_{R'} = 0.1811$	0.2891	0.2893	0.2468	0.2075	0.1764	0.1030

7.9.8 General conclusions on inflationary situations

In the case of high rates of inflation, the phenomenon of general inflation of all factors which are involved in the discounted cash flow predominates, and the use of values in stable currency leads to a determination of the real internal rate of return. However, inflation produces a need for continuous contributions to working capital which causes reductions in the profitability that can reach relatively high values.

This can be corrected, where possible, through increases in the margin of sales, or by use of loans. In this case it has been shown that its effectiveness is lost as inflation increases, and can lead to adverse effects. In particular, indexed loans (among which, foreign currency loans whose rate of exchange follows the rates of general inflation) pose a high risk, since, if the inflation rate were increased, considerable losses would occur.

The equations obtained for cash flows with results repeated over time quantify these concepts, presenting values calculated in tables as a function of dimensionless parameters which represent the relationship of sales over operating costs, operating costs over fixed investment and working capital over sales. A generalization of the continuous case would indicate the need for short-term analyses, since analysis in annual periods could lead to wide errors in the case of high rates of inflation.

The generalized commercial practice of increasing the sales margin (to cover the replacement cost), would lead to a self sustained inflationary process, which is difficult, if not impossible, to control through the mechanisms of classic economics.

The combination of all these factors, with annual variable output and variable rates of inflation, can only be resolved through a discounted cash flow, including the concept of real profitability defined by expression (7.32). However, the formulas presented as a function of dimensionless parameters give a useful general idea of decision-making on strategies to be used in the event of high inflation rates.

High inflation rates, or just inflation, it is not a situation usually sought or desired by an industry, but a situation to be faced and overcome in order to survive. From experience in countries with high inflation rates, it is clear that most of the management effort in such situations is directed towards developing financial strategies in order to survive. Other aspects, like market and technological development and quality, receive less or no attention. Unfortunately, relatively high inflation rates continue to be a problem in many developing countries. Therefore it has been found necessary to include this analysis - certainly not restricted to the fishery industry - to provide appropriate tools to the interested reader.

8. QUALITY AND SAFETY ECONOMICS

8.1 Introduction

A necessary objective of the fishery industry is to deliver a wholesome and edible product and the necessary auxiliary services fulfilling a number of requirements and features known generally as quality (in the understanding that safety is the first stage and *sine qua non* condition for quality). Therefore, it follows that a joint analysis between economics and quality of the food or fishery product delivered will also be needed at company level.

The economics of safety and quality of fish and fishery products despite its practical importance, has received comparatively little attention till now. As pointed out by Bonnell (1994) regarding Atlantic Canada's seafood industry, there are relatively very few industries in this sector that apply the concepts and techniques involved in quality economics. The difficulty in determining and analysing quality costs in practice, particularly in the food industry, is recognized in the literature (Hosking, 1984) (Crosby, 1980) (Morgan Anderson, 1984). However, it is already a very important management tool, for instance in the Scandinavian fishery industry (Drewes, 1991; Valdimarsson, 1992).

Quality economics analysis will become increasingly more important to the fishery industry worldwide. The first reason is that quality is becoming a marketing tool (particularly in demanding markets), the second is the need to implement Hazard Analysis Critical Control Point (HACCP), as requested now by regulations in many developed and developing countries, for instance Canada, those of the EU, Brazil, Thailand, and Uruguay.

In addition, since unsafe products are at the basis of foodborne disease outbreaks, Governments are also gaining interest in the matter, due to the impact of the lack of food safety on public health budgets. This situation is compounded in practice with the steady increase of the cost of medical services, consumer awareness, pressure to reduce public expenditure and citizen's opposition to tax increases.

8.2 Fish Safety and Quality

Food and fish safety is defined in practice with reference to public health regulations, the purpose of which is to define the basic conditions for the wholesomeness and edibility of a given type of food. As very often consumers are not personally able to determine if a given product is apt or not for consumption (e.g., levels of histamine, Hg, absence of pathogens) Governments apply sanitary policy to pass and enforce regulations.

Specific regulations vary from country to country (FAO, 1989) as well as the procedures for enforcement. To meet the safety regulations and the minimum quality level of a given State are a pre-requisite to enter its market.

Quality is not easy to define. Different people give different definitions or underline different quality characteristics or features, even speaking of the same type of product. As philosophers have by now agreed the word "quality" does not appear to be definable.

Nevertheless, practical definitions can be found in the literature, for instance according to the standard ISO 8402 quality is "the totality of features and characteristics of a product of service that bear on its ability to satisfy stated or implied needs". This is certainly open to interpretation, since almost anything could qualify as an "implied need".

It is in practice a working definition of quality (in this case a definition with didactic purposes).

From recent papers where the subject of fish and food quality is discussed (Lee, 1994; Sloan, 1994), there seems to be at least three groups of characteristics and features that contribute to quality:

(a) Characteristics and features of the product that can be directly measured or assessed. For instance weight, shape, temperature, fish species, colour, taste, texture, size, homogeneity, composition, oil content, etc. Most of these characteristics and features are normally specified in the seller-buyer (wholesale) contract.

(b) Characteristics and features of the product that can have a desired or undesired effect on human health. For instance, nutritional value (desiderated), pathogens counts, Hg, histamine, pesticides, paralytic shellfish poisoning, etc. Most of these characteristics and features are usually defined by law although they may be incorporated to contractual agreements. Recently, characteristics related to environment and ecology (that could create problems to human beings in the medium and large term) are added to this group (e.g., recyclability and biodegradability of packaging).

(c) Characteristics and features of the services involved with the product; including consistency in the quality of different shipments and within a shipment, integrity (in trade), communication and keeping time. Most of these are usually part of expected customary and ethical trade practices, although some may form part of local regulations or be included in contractual agreements.

Each market, each buyer, will have a working definition of quality that encompasses characteristics and features of (a), (b) and (c). The producer must know the working definition of the aimed market in order to succeed in business.

Despite the complexity there is in practice a simple parameter against which quality is measured; and that is money. The price of the product (or competitive price) (Lee, 1994; Sloan, 1994) is at the same time a quality feature and a parameter that reflects the influence of all the others, including the influence of production cost. However, price, isolated from the other characteristics and features, should be viewed with caution.

Depending on the product and the market, the complete working definition may be more or less complex. It is advisable to specify numerical values for the characteristics and features whenever possible, limit values should be clearly specified, and in the case of using words, they should be unambiguous and concise.

The industry that manages to produce at the required level of quality, at minimum cost, will have a comparative advantage over competitors. This is basically the strategy of companies that utilize quality as a marketing tool.

8.3 Quality Economics Analysis

Quality economics is a very wide subject. A common misconception is that it is solely related to certain type of costs and aimed at reducing them. Although in practice most of the available literature is related to "quality costs", quality economics analysis is applied because an increase of profit (see Chapter 7) is pursued, and not just as a result of cost reduction.

As stated by Sterling (1985), after the implementation of a quality assurance programme at Nabisco Brands Inc. (USA):

"We had to spend money to implement our programs. New technical positions and staff increases cost about US$ 1.5 million per year. But our payback was more than US$ 2 million, US$ 1 million related to quality, and more than US$ 1 million related to cost improvement.We could never have obtained cost improvement until we had the system to ensure quality."

A similar trend, quality improvement - cost reduction - profit increase, has been observed in the Danish fishery industry (Drewes, 1991).

The reason for this relationship is rooted in the fact that the true application of quality assurance (or HACCP) requires an in-depth technical knowledge of the processes and operations involved. Once this technical knowledge is gained, it allows to identify and control more easily non conformance costs. At the same time improved quality allows the firm to secure better prices, increase the market share, etc.

Example 8.1 The Case of Fresh Fish Fillets carrying the US Grade A Shield (Gorga *et al.*, 1979) (Gorga *et al.*, 1982)

In 1974 the Gloucester Laboratory of the National Marine Fisheries Service (NOAA) of USA initiated, in association with some fishery industries and supermarkets, the basic experiment to introduce the US Grade A quality shield. The Gloucester Laboratory "found it necessary to design and to implement a strategy to convince the US seafood industry that it pays to assure the quality of its products to the consumer."

Within six years the sales volume had reached eleven million lb, with a value of about US$ 30 million, and included fifteen northeastern States. Today, the US Grade A quality shield is utilized throughout the US territory. A key point of this development was the quality related economic analysis, performed at the end of the project in 1976.

"At the end of the project, an economic analysis was made, and when the findings were extrapolated to an activity involving a production rate of 10 000 lb of fish fillets/day, an efficient production rate, the analysis showed that the unit cost to assure quality was US$ 0.10/lb. The analysis also showed that even this added cost was nullified because quality assurance helped eliminate losses due to spoilage and to markdowns. Thus the analysis showed that it required no added cost to assure quality."

The initial study also revealed that consumers were willing to pay up to US$ 0.50/lb more for guaranteed quality fillets than for fillets whose quality was not guaranteed by the US Grade A shield, and by the implicit pledge of the retailer to withdraw from sale those products which were about to fall below the established quality grade.

This project was conducted "without the inclusion of fishermen, whose involvement - although not essential - was vigorously attempted without success, the quality control and inspection activities that are required to assure quality started at the point of landing rather than at the sea."

This is a very interesting example; points deserving further analysis and comments include the following:

- The relationship between cost increase due to increased quality and profit.
- The need of involvement of all concerned through to the final consumer.
- The possibility of an official research laboratory to be involved in a technical/economic experiment to improve fish quality at retail points.
- The need for a careful evaluation of production costs during the experiment, and skilful extrapolation of the results.

8.4 Production Cost and Quality Cost

Actual production cost, as discussed in Chapter 4, is the cost of producing a given product at a declared level of safety and quality.

Production cost is composed of variable or direct and fixed costs. Although most of the literature dealing with "quality costs" refers to optimization of variable costs (see section 8.5) this is misleading. Optimization of variable costs could be of no avail if fixed cost is high or low. With a high fixed cost, optimization of variable costs may be not enough to make a cost competitive product, even if quality is right. In the case of low fixed cost, the plant, equipment, etc. may not be in a position to yield a product of the desired quality.

There is no single type of cost, or group of them, as defined in Chapter 4, that could be identified as "quality costs". All contribute in one way or another to total production costs and to the quality associated with the product. However, as will be discussed in section 8.5, it is possible to identify some quality related variable costs that can be controlled by management in order to minimize production cost (for a given fixed cost structure).

8.4.1 Design and investment to produce quality (fixed cost)

Fixed costs, in particular depreciation, are determined at the design and investing stage. The quality level and the necessary costs to produce it, are analysed and decided at the design stage. Figure 8.1 shows conceptually the comparison between the value assigned by buyers or consumers at a given level of quality and the quality cost to produce it.

Depending on the type of product, a quality that maximizes the profit will be chosen (schematically in Figure 8.1, a quality level between 3 and 4). This quality level will resolve the quality objectives that should concord with the quality requirements of the customers (contractual or implicit agreements). Quality objectives and quality costs should be re-checked later, after production starts.

In Figure 8.1, five arbitrary levels of quality values are indicated (e.g., the quality levels of fresh fish), together with the corresponding five levels of quality costs. As quality increases the corresponding quality costs will also increase. At a certain point the quality cost may become prohibitive and will equal and even overtake the quality value (e.g., wild marine fish from clean unpolluted waters to be served shortly after capture, marketed on a commercial scale).

Failure to achieve quality objectives (established by design or implicit) can stem from three causes: (i) unrealistic initial objectives, (ii) inadequate hazard analysis, or (iii) failure

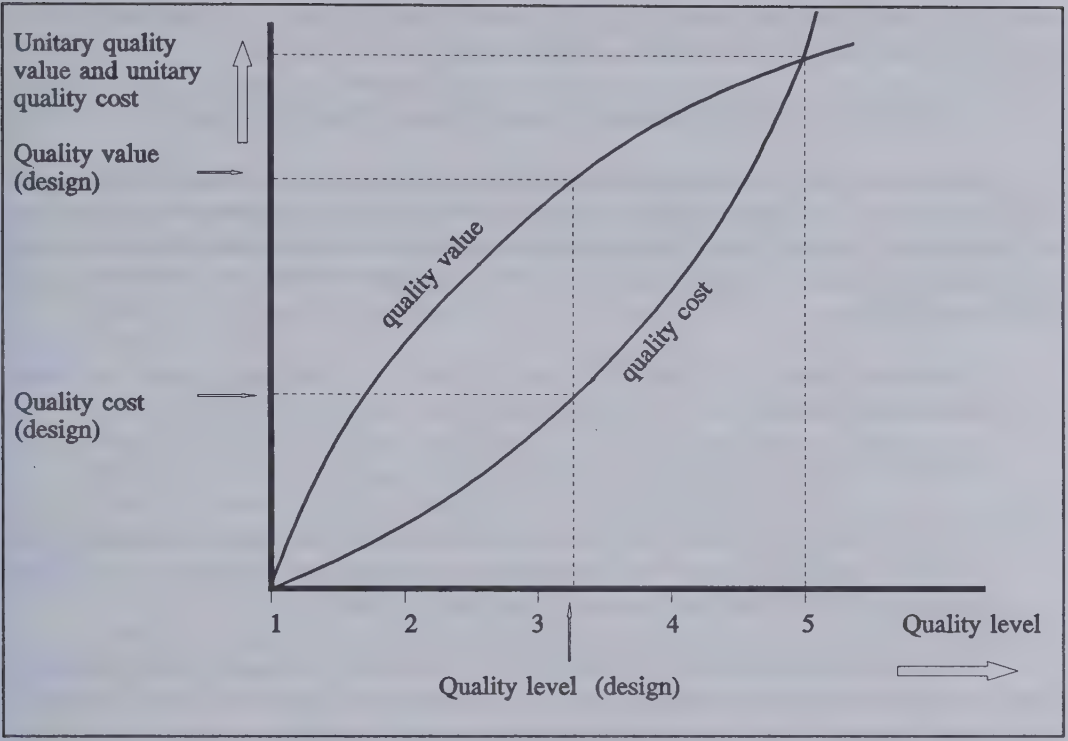


Figure 8.1 Quality Costs at the Design Stage

to implement the requirements properly (IFST, 1991) (Pearce, 1987). In particular the first two are clearly linked to initial investments (e.g., pre-project study and analysis expenses, selection of main equipment and design of production lines, storage rooms and distribution).

Figure 8.1 shows that it is not a good business for a company to produce at "the maximum" possible quality, and that low quality is a bad business. A good design puts "optimum" quality a value above the minimum quality level, fixed by food safety considerations (public health) and public acceptance.

The costs of solving a problem increase exponentially the further the work has progressed into the development and production life cycle before the fault has been discovered. From that point of view a proper design is a preventative measure.

The overall objective will be the design with minimum costs at specified quality. Whereas the main aspects of fish processing and characteristics of fishery products are generally well known, the way to produce fishery products of a given quality, particularly high quality products at a minimum cost, is becoming a guarded secret. This is primarily due to the investments made in the plant design, and in the selection and implementation of the QA methodology.

For example, this phenomenon can be observed in the smoked salmon industry of Northern Europe. Design and quality assurance methodologies are becoming part of industrial know-how in the fishery industry. The introduction of electronic scales and machines that can be connected directly to microcomputers are concentrating, collecting, elaborating and providing on-time information to comparatively fewer people within the plants, making it easier to control actual costs and at the same time maintaining secrecy on overall procedures, results and parameters (Valdimarsson, 1992).

8.5 The PAF (Prevention-Appraisal-Failure) Model of Quality Costs

Feigenbaum (1974) proposed a model to analyse quality cost that is almost universally accepted (Plunkett and Dale, 1987; Porter and Reyner, 1992). This model assumes that production costs relevant to quality changes can be divided in three categories: prevention costs, appraisal costs and failure costs, and can be defined as follows (British Standard Institution, 1981):

> **Prevention costs.** The costs of any action taken to investigate, prevent or reduce defects and failures.
>
> **Appraisal costs.** The costs of assessing and recording the quality achieved.
>
> **Failure costs.** The costs arising from failure to achieve the quality specified. These can be divided into internal and external costs, whether they are produced within the plant or after the transfer of ownership to the customer.

The model assumes that PAF costs can be identified, measured and particularly controlled, this means that they can be varied as a result of management decision. Therefore only variable costs, within production costs are usually considered. Fixed costs (e.g., depreciation) are not considered. These categories of quality cost are limited to the analysis of costs of conformance and costs of non-conformance.

This techno-economic analysis can be done for example, following the guidelines for the determination and use of quality related costs of standards such as the BS 6143:1981 (British Standard Institution, 1981), the Australian standard AS 2561-SAA, 1982; or the procedures recommended by the American Society for Quality Control (Hagan, 1986; Moore, 1977). The interested reader should be aware that such standards are general and not specific to the fishery industry.

Quality costs are not easy to determine from ordinary reports and accounts, and should be identified first and recorded separately on a subsidiary ledger or memorandum account.

Quality costs are usually analysed following the Pareto principle: few factors account for the largest portion of the costs. These are often referred to as the "vital few", while remainders are the "trivial many". The Pareto principle can be a useful tool in analysing quality costs. It allows for a large proportion of the costs to be accounted for with relatively little effort or expense (Sandholm, 1987).

8.5.1 Prevention Costs

These are the costs of activities aimed at preventing defects occurring during the development, production, storage and transport of a product. They relate to quality before a single unit of product is made. They usually represent up-front costs that should minimize overall costs by performing the task properly and hopefully at the first attempt.

Prevention costs received little attention in the past when classic quality control (QC) and inspection were applied, but with the introduction of HACCP and quality assurance (QA) concepts, they became an essential component of the quality cost scheme. Components included within prevention costs are usually the following:

- Costs involved in planning and documenting the Company's quality system (including establishment of product specifications). Quality planning is done by QC or QA personnel and involves setting up programmes for process control. Quality planning activities may be also carried out within a Company by other departments (e.g., Purchasing, Research and Development, Production Planning and Scheduling and Sales).

- Costs of directing, administrating, executing and auditing QA activities (including salaries). In the case of the Example 8.2, all costs are directly linked to this item.

- Costs of planning and implementing training and motivational programmes in quality operations and attitudes.

- Costs of industrial safety programmes and measures. This is very important in the fishery industry, particularly onboard fishing vessels and during fish handling and processing.

- Preventative maintenance on processing equipment. This includes the cost associated with necessary repairs and adjustments.

Example 8.2 Prevention Costs. Cleaning Costs in the Australian Seafood Processing Industry (Dunsmore *et al.*, 1983)

Cleaning is one of the key activities in the prevention of failure costs of fish processing plants. Cleaning it is not an aesthetic operation or just a general hygienic procedure but a preventative measure. As such, it is necessary to analyse procedures and costs in order to study its cost-effectiveness.

During 1980 a survey was conducted on costs and cleaning practices in twelve Australian fish handling and processing facilities. Findings are detailed in Table 8.1. This case study is also particularly useful in discussing the need of applying the economic engineering approach in the analysis of quality costs.

In this instance, the need for proper equipment and processing lines design to facilitate cleaning is clear (saving cleaning time means saving labour, and reducing hygiene risks), and the investment in training of operators (to carry out and follow the proper cycle of cleaning operations).

Table 8.1 shows wide variation in costs associated with cleaning, even within the same type of industry. Plants 1 to 5 were general processors, plant 6 was for specialized prawn processing, plants 7 to 9 were smaller enterprises.

Table 8.1

Costs of Cleaning at 12 Locations in the Australian Seafood Industry

Type of industry	Total Cost (1)	Detergents and Sanitizers (1)(2)	Cleaning Equipment (1)(2)	Labour (1)(2)
1. Finfish/prawn	5 247	761 (14.5)	136 (2.6)	4 350 (82.9)
2. Finfish/prawn/lobster	8 662	3 024 (34.9)	418 (4.8)	5 220 (60.3)
3. Finfish/lobster	2 948	848 (28.8)	100 (3.4)	2 000 (67.8)
4. Finfish/prawn/scallops	9 661	1 920 (19.9)	2 066 (21.4)	5 675 (58.7)
5. Finfish/prawn	15 199	6 093 (40.0)	1 006 (6.6)	8 100 (53.4)
6. Prawn	73 847	3 408 (4.6)	429 (0.6)	70 000 (94.8)
7. Oyster	2 401	188 (7.8)	88 (3.7)	2 125 (88.5)
8. Oyster	4 663	84 (1.8)	13 (0.3)	4 566 (97.9)
9. Oyster	2 254	279 (12.4)	72 (3.2)	1 903 (84.4)
10. Crates (3)	34 865	365 (1.1)	4 000 (11.6)	30 000 (87.3)
11. Finfish boat	229	0	2 (0.9)	227 (99.1)
12. Finfish boat	220	0	2 (0.9)	218 (99.1)

Notes:
(1) All values in $AUS (1980)
(2) Value within brackets indicates percentage of total cost
(3) Fish box cleaning facility at a fish market

This review does not indicate plant capacity or actual levels of production that would be useful for comparison purposes, but offers the following useful information for analysis and discussion:

- Overall labour comprised the bulk of costs (average 84.2%), with detergents and sanitizers only a minor part (average 10.6%), and cleaning equipment even less (average 5.2%).

- Lower expenditure was found aboard fishing boats. They were cleaned with water and scrubbing brush without using detergents and sanitizers. According to the investigators, "the situation on the surveyed fishing boats was particularly disturbing", because "the same standards of hygiene should apply on boats as in other efficient food-handling operation" (Dunsmore et al., 1983).

- Even in the case of the crate-washing plant that had an automated line to clean the fish boxes, the main cost item was labour. Table 8.1 includes the annual depreciated costs of the cleaning equipment.

- Highest expenditure was found in plant 6, specialized in prawn processing for local consumption and export. It was the only one to be cleaned twice each shift (e.g., at lunchtime and after the cessation of processing).

- Cleaning systems utilized are also analysed. The general conclusion was: "Unfortunately, none of the systems used in the surveyed plants incorporated all of the components required for effective detergency or sanitizing" (Dunsmore et al., 1983). For instance, plant 6 followed the correct procedures with regard to some sections and equipment, but not throughout the plant.

8.5.2 Appraisal costs

These are the costs of inspecting and testing to ensure that the products, parts and raw materials conform to quality requirements. These are generally the easiest type of quality costs to measure and include:

- Costs related to the in-plant (internal) inspection and control of raw materials, purchased ingredients and packaging.

- Costs related to in-plant (internal) process inspection, such as checking of semi-processed items and final products, temperature inspection and recording, including costs of compilation of quality records (cost of the forms and clerical expenses).

- All the in-plant laboratory costs (including sampling and testing). This item also includes the cost of disposable laboratory equipment and material (chemicals, microbiological media, glassware, etc) calibrating equipment and any outside testing services that may be used.

- The salaries of quality control and inspection people (professionals, technicians and workers).

- Costs related to final inspection, in-plant or external. Official final inspection certificates are mandatory in some countries, and the firm should pay for them to the Government or specialized Government Agency (e.g., to CERPER in Peru). In some cases in accordance with a contractual agreement, a final certification from a third independent laboratory may be required.

As temperature is the single most important parameter in HACCP implementation, the costs related to measurement, recording and control of temperature, including calibration of equipment, should be included as appraisal costs. The level of costs of this item can be a good indicator of HACCP implementation.

According to the new regulations in Canada, USA and the EU, now being implemented, fishery products manufactured outside the proposed HACCP-based systems will have to pass through independent full sampling and analysis. If applied, these regulations will increase the appraisal costs of the companies that do not conform with the new regulations.

Example 8.3 Costs of Microbiological and Chemical Analysis

The cost of objective and subjective analysis to determine safety and quality of fishery products is a key component of appraisal costs. This type of cost can be due to internal or external (voluntary or mandatory) quality control and inspection. In principle, cost of analysis is easy to determine. It comprises the cost of chemical reagents and media, disposable glassware, analyst's time (sampling, sample preparation, travel time, analysis time, time of analysis interpretation and reporting and dead time), energy (some analyses require notable use of electricity), cost of samples and administrative overheads.

If fixed costs are to be included in the picture, the proportion of depreciation of the laboratory, facilities and equipment should be added. As discussed in section 8.4, at company level, fixed costs are treated separately of variable costs. The inclusion of a laboratory in a plant will depend on an economic comparison of the cost of performing the analysis in-plant or contract a external laboratory to do them.

Small plants may find more convenient to contract a laboratory service rather than to have their own; however, this will depend on the volume of production, type of product and legal and contractual requirements.

(i) Cost of external analysis

It may be difficult to determine the cost of in-plant analysis, because in practice very often the analyst is used in many other functions, e.g., procurement of permits, discussion with official fish inspectors, product development, in-line quality supervision, quality auditing, supervision of cleaning personnel, pest control, responsible for industrial safety, fire warden, etc. However, it is relatively easier to establish the cost of external analysis.

In Table 8.2 the cost of different types of analysis, performed by a third party, is listed. In the case of Canada and Mexico the cost that appears in Table 8.2 represents the total cost of the analysis; in the case of USA the cost will depend on the time used by the NMFS officer to draw the sample and travel, plus mileage cost and administrative overheads.

From Table 8.2 it is apparent that costs of analysis vary widely, in developing countries they may be less expensive, because of low wages. However, the advantage of low wages may be offset by the increased cost of reagents, media, glassware and equipment that should be imported, and sometimes labour productivity.

Table 8.2
Cost (in US$) of some Microbiological and Chemical Analysis on Fish Samples

Type of Analysis	Canada (1)	USA (2)	Mexico (3)
Faecal coliforms	129.16	23.96 (4)	13.63
E. coli	162.5	35.94 (5)	30.30
S. aureus	112.5	17.97	22.72
Salmonella spp.	154.16	47.92 (6)	22.72
L. monocytogenes	200	n.a.	n.a.
Mercury	100	n.a.	45.45
Histamine	112.5	71.90	n.a.
Shellfish toxin	70.83	51.05 (7)	n.a.
Ammonia	n.a.	53.92	n.a.
Species identification	170.83	71.90	30.30 (8)

Notes:

(1) Fish Inspection Regulations, Canada, version of 1992, values in US$ (calculated at a rate of 1.2 $CAN per 1 US$). Reinspection fees are higher than those that appear in this table (e.g., reinspection analysis for histamine costs US$ 183.33).

(2) National Marine Fisheries Service (NMFS), USA, 1992, values in US$. Cost for analyses only, hourly charges for lot, miscellaneous, consultative and inspection services plus a 20% surcharge for administrative purposes should be added.

(3) Centro de Investigación en Alimentación y Desarrollo, A.C. (CIAD), Mexico, 1994, values in US$ (calculated at a rate of 3.3 MN$ per US$ 1).

(4) The basic analysis is Total coliform that cost US$ 11.98, to determine Faecal coliform US$ 11.98 should be paid in addition.

(5) The basic analysis is Total coliform + Faecal coliform (see previous note), to determine E. coli US$ 11.98 should be paid in addition.

(6) BAM method (steps 1, 2 and 3).

(7) Paralytic shellfish poison (PSP), cost per sample (minimum of 3 samples).

(8) On meat.

(ii) Cost of lot sampling and inspection services

The hourly fees for inspection services rendered by the NMFS (USA) are listed in Table 8.3. If the values for USA of Table 8.2 are consolidated with values of Table 8.3 (Type II, for sampling), administrative surcharge (20%) plus eventual travel, costs of analysis in USA and Canada became more or less of the same order.

Tables 8.2 and 8.3 indicate the additional cost created by fish shipments being placed in detention upon arrival in the USA (in this case analysis costs could be part of a failure cost, see section 8.5.3.2). In the case of USA private laboratories could be called upon by the competent authority to perform inspection analysis on request. In this case, costs are charged at the current cost of the private laboratory.

Table 8.3
Hourly Cost Fees for Inspection Services (voluntary scheme) charged by the US NMFS (1992) (1)

Type of services	Regular time US$/h	Overtime US$/h	Sunday and legal holidays US$/h
I Official establishments and product inspection	32.45	48.70	64.90
II Lot inspection. Officially and unofficially drawn samples (2)	45.45	68.15	90.90
III Miscellaneous inspection and consultative services (3)	40.55	60.85	81.15

Notes:

(1) Excluded the states of Alaska and Minnesota. A 20% of the total will be charged for administrative purposes.

(2) Minimum fee US$ 34.10. It includes sampling and travel time (mileage costs are assessed separately).

(3) Minimum fee US$ 30.45.

(iii) Influence of the number of samples

The type of analysis and the number of samples for each shipment are determinant in defining the total appraisal cost, particularly in fish inspection and quality systems based on analysis of final products.

The number of samples to be analysed depends on the size of the lot, and on the degree of reliability pursued. In the case of fish inspection, regulations could specify the number of samples to be drawn from a lot. For instance in the case of the Canadian Fish Inspection Regulations the sample size, for organoleptic evaluation, should be determined in accordance with Sampling Plan I (for first inspection) and Sampling Plan II (for reinspection) as specified in "Sampling Plans for Prepackaged Foods" (FAO/WHO, 1969). A case for a lot composed of product units with a weight equal or less than 1 kg each, is presented in Table 8.4.

As costs presented in Tables 8.2, 8.3 and 8.4, in particular those referring to Canadian and American Public Services, are fees aimed to recover "as nearly as possible" the costs of providing the inspection service, they can be used as a base to calculate the cost of analysis in developed countries. Private laboratories will usually charge higher fees than official laboratories, and report or certificates produced may have not the same legal value of those of official laboratories. However, it is very common that seller and buyer may agree on a private laboratory to check lots, since obviously official laboratories cannot cope with all the existing trade.

Table 8.4

Cost of Sensory Evaluation (in US$), in Function of Lot and Sample Size, and Acceptance Number, for Inspection and Reinspection of Fish Lots, according to Canadian Regulations (1) (2) (3)

Lot size (N)	Sample size (n) (4)	Acceptance number (c) (4)	Cost (US$) (4)
4 800 or less	6 (13)	1 (2)	58.3 (129.2)
4 801 - 24 000	13 (21)	2 (3)	70.8 (170.8)
24 001 - 48 000	21 (29)	3 (4)	83.3 (270.8)
48 001 - 84 000	29 (48)	4 (6)	125.0 (395.8)
84 001 - 144 000	48 (84)	6 (9)	170.8 (666.7)
144 001 - 240 000	84 (126)	9 (13)	270.8 (979.2)
More than 240 000	126 (200)	13 (19)	383.3 (1 429.2)

Notes:

(1) Fish Inspection Regulations, Canada, version of 1992.

(2) Values of N, n, AQL (6.5) and c, according to Sampling plans I and II (reinspection) for product units with a net weight equal or less than 1 kg (2.2 lb). Determined in accordance with (1) and (FAO/WHO, 1969).

AQL: Acceptable Quality Level. Maximum percentage of defective units permitted in a lot, which will be accepted approximately 95% of the time. A sampling plan with AQL of 6.5 will accept a lot or production which has 6.5% defective approximately 95% of the time.

c: Acceptance number. Indicates the maximum number of defectives permitted in the sample in order to consider the lot as meeting the requirements of the FAO/WHO CAC/RM 42.

(3) Values in US$ calculated at the rate of 1.2 CAN$ per US$ 1 (1992).

(4) Values in brackets correspond to reinspection, according with Sampling plan II (n and c), and respective reinspection fees.

In practice, an exporter may be put in the situation to pay for the quality appraisal of a lot more than once. It may expend to check at plant level, then pay for the local fish inspection and finally been affected by the inspection cost at the importing country. Although national regulations in general establish that inspection analysis "shall be payable by the person that imports the fish" (Canadian Fish Inspection, Cost Recovery Programme), it is clear that such cost will influence the amount to be paid for the lot to the exporter.

If all the cost analyses are compounded, the appraisal costs can become very high. In that situation it is not unusual that "commercial sampling" has been agreed by seller and buyer, this means in practice less demanding sampling, each time, that such detailed in Table 8.4. Depending on the type and value of the product, if it is a final or intermediate product, size of the lot and type of analysis requested fewer samples can be drawn.

For instance according to Canadian regulations, for bacteriological examination of fresh and frozen fishery products the sample size should be 5 individual prepackaged units or five 1-lb sample units from large bulk containers (Emberley, 1991). This in turn fixes the mandatory cost of the analysis; e.g., the analysis of *Salmonella* spp. (see Table 8.2) will cost US$ 770.8, regardless of the size of the lot.

In general, small lots will have a comparatively high appraisal cost and a relatively low statistical reliability, even if FAO/WHO sampling plans are followed. Exports from developing countries usually face this type of problem. The analysis of Table 8.4 while giving an indication of the possible costs of sensory evaluation, immediately raises a number of issues: the comparatively large number of defective lots that may be accepted, the risk involved in accepting "bad" lots, and the existence in practice of "zero" tolerance limits (e.g., *Salmonella* spp.).

The number of samples to be analysed can be increased in order to reduce the risk of acceptance of faulty lots. However, reliability does not increase proportionally to the number of samples as will be discussed below.

(iv) Cost of increasing reliability through the increase of the number of samples analysed

Following with the sensory analysis presented in Table 8.4 it could be hypothesized that there is a product with lots containing 4 800 or fewer units of 1 kg each, with 20% of defective units. Applying Sampling Plan I according to Table 8.4, 6 samples will be drawn for sensory analysis, and the cost of the analysis will be US$ 58.3 .

From the analysis of the corresponding Operation Characteristic Curve (OCC), (see FAO/WHO, 1969) it will result that the lot will be accepted in approximately 65% of the cases, or conversely approximately 35% of the lots in such conditions will be rejected under this sampling plan. At this point the purchaser or importer who discovered that the lot contained a large portion of defective units may be inclined to request that more samples be analysed in future shipments.

What degree of reliability is required (in percentage of rejected lots with such characteristics)?, how many samples?, and how will the cost increase?. Using Sampling plan I (AQL 6.5) and, the corresponding OCC, it is possible to construct Figure 8.2. Although the curve drawn in Figure 8.2 indicates only tendency (available cost values are for a fixed number of samples) it is clear that under such a sampling plan, the increase in reliability (or in assessed quality) will imply a exponential increase of the appraisal cost (see Figure 8.3).

It is pointed out that increased sampling will not eliminate the risk of acceptance of "bad" lots. In the example of Figure 8.2 it was assumed that 20% of the units within the lot were defective, but, this is a hypothetical situation (in practice it cannot be know how many defectives there are in a lot). What happens for instance if instead of 20% defectives there are only 10% defectives?

Assuming that in the example of Figure 8.2, it had been decided to have a sampling of 48 units (1% or more of the total lot!) to assure a 87% of rejections of lots containing 20% of defectives, it happens that lots with 10% defective units will be accepted in approximately 78% of the cases, or rejected only about 22% of the time.

From a cost point of view this can be a nightmare situation for a small and medium company. Following the example of Figure 8.2, the increased reliability from 35% rejections (n = 6) that will cost US$ 0.012/kg of sensory evaluation, to 87% of rejections (n = 48), will increase the cost of sensory evaluation alone from US$ 0.012/kg to US$ 0.036/kg (figures can be higher than indicated if the lot has less than 4 800 units).

This increase in the cost of analysis does not include the cost of the samples (that should be included) and eventually the cost of other required analysis (e.g., microbiological). For example, assuming a total cost of US$ 1 per unit (US$ 48 in addition), plus a faecal coliform analysis (US$ 390.48), the total cost of analysis will reach US$ 0.127/kg. This is 12.7% of the total cost; and if defective units are below 10% of the lot, they will be accepted 78% of the time.

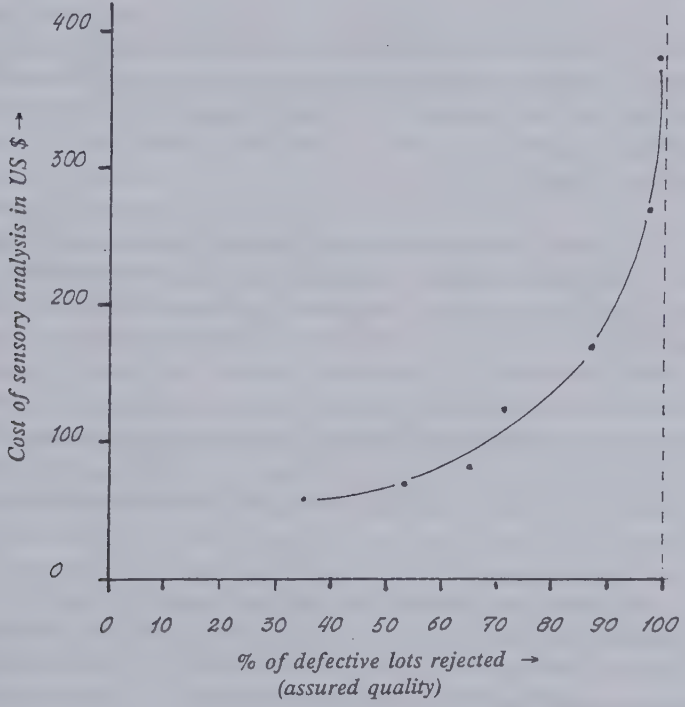


Figure 8.2 Variation of the Cost of Sensory Analysis vs the Increase in Reliability (approx. percentage of rejection of a lot containing 20% of defective units)

(v) The economic need to assure quality through other means

The example discussed in point (iv) is illuminating regarding the economic impossibility to assure (not **control**) quality through the analysis of samples of the final product. Although the incidence of cost of analysis can be reduced by increasing the number of units of a lot, it may create other problems, such as lack of consistency of the quality within the lot (because it is actually made up of a number of small lots, e.g., formed by the processing of different lots of raw material).

Although it is rarely admitted, the number of analyses prescribed by the regulations of some countries are impossible to meet just for cost reasons. They are only enforced when an outbreak occurs (e.g., cholera, SPP, salmonellosis), in the case of lots of dubious origins, or when the producing company (sometimes the country of origin) has poor records of safety and quality. Those regulations may be used as non-tariff barriers, but in view of the nature of the international fish market those moves are necessarily short-lived (the suppliers will look for alternative markets).

Nevertheless, there is the need to produce safe products of consistent quality. The liability continues to subsist regardless of whether or not the specific analysis was performed. At the same time the customers require products of consistent quality if they are to purchase them again. The only possibility of responding to such requirements is to develop safer production methods aimed at avoiding safety and quality problems, designed, operated and controlled in order to obtain and deliver the right product, the first time. Regulations on Good Manufacturing Practices (GMP) and FAO/WHO Recommended Codes of Practice were and are still in use.

More recently HACCP and HACCP-based methods have received wide recognition because they present a more systematic and precise approach, are relatively easier to harmonize at regional and international level, and focus on essential safety aspects. In addition to other possible approaches, HACCP has been applied since 1976 in the canning industry with excellent results.

However, to be useful any method should be more cost-effective than the one it is intended to replace. GMP and Codes of Practices allowed, when properly applied, to lean on fewer demanding sampling systems, but neither eliminate the need of analysis nor the problems due to defective productions. Application of HACCP and HACCP-based methods, according to the existing experience of the canning industry, can reduce even further the need of analysis, and at the same time the problems caused by defective products. Further discussion on the cost of applying HACCP to the fishery industry is presented in section 8.6.

(vi) There are a number of practical projects that the reader can attempt, departing from this example, viz.:

- The actual cost of analysis in the company/country, or for a given product
- The incidence of appraisal costs on the total selling price (ex works) of a product
- The total cost and economic viability of full applying a given national regulation
- The economic feasibility of a "zero" defect product

8.5.3 Failure costs

This is the highest type of quality cost in virtually any operation. It includes product and process failures that become evident and those which do not (hidden costs).

8.5.3.1 Internal failure costs

Internal failure costs include the following:

(i) Scrap

Products, parts and materials that cannot be used because they do not meet the quality requirements. It refers to final products, intermediate products, ingredients, packaging, etc., that should be discarded voluntarily or compulsorily (in the case that official fish inspection be inside the plant), before being sold. This is a direct loss and should include all the material, processing costs and labour costs incurred in production. In particular, it includes the quality aspects that relate to yield, wastage (raw materials, intermediate products, final products, energy, labour, facilities), sub-standard products (not reprocessed) and mark-downs (also called downgrading) due to poor quality.

(ii) Reprocessing

With regard to reprocessing, a fish processing material could have salvage value and can often be reprocessed into a new product. It should be borne in mind that this is really a cost, not a recovery. Generally all that is recoverable from reprocessing is the value of the fish, because in most cases the original processing costs, labour costs, and packaging material costs are lost. A typical case in the fishery industry is repackaging due to wrong labelling.

Other costs associated with reprocessing could be: re-inspection, screening (sorting out defective individuals from a batch found to have too many defective fish), and defect analysis, to identify the causes of the internal failure cost. In practice, a reprocessing activity in the fishery industry may be masked.

In the example presented in Figure 2.6 , the influence of the quality of raw sardines on the productivity of the nobbing operation was discussed. The same example could be analysed from the viewpoint of quality costs, since the screening (sorting out of the defective sardines showing belly burst) introduces increased labour cost and a cost associated with a less-than-satisfactory use of the nobbing machines.

(iii) Other costs

There are a number of other internal failure costs that may pass unnoticed in normal plant operation but that should be accounted for. For example, cost of additional laboratory analysis to ascertain the quality of dubious lots, extended cold storage of lots that could not be dispatched due to low quality, costs produced during the analysis of faulty lots (including salary), energy losses due to improper use of ice, electricity, steam and water, faulty operation of the cold storage room, low fish yield of untrained staff, low fish yield due to improper adjustment of fish processing machines (e.g., filleting machines).

An example of this type of internal failure cost is the so-called overall shrink (or cold storage/chill room storage losses). Shrink is the loss of inventory due to spoilage, deterioration, water loss and uncontrollable acts. In the US fishery industry an average for fresh fish overall shrink is 10%, and 1% for frozen fish (Source: Food Marketing Institute - FMI - Retail Produce Operations 1986).

Example 8.4 Energy Consumption in Tanzanian Ice Plants

Production of ice is itself a commercial activity. To economize on overall performance, production costs should be kept to a minimum. Energy costs in particular should be closely controlled. The energy required to produce 1 t of ice varies depending generally on the type of ice maker and prevailing climatic conditions. In the tropics, it ranges from 55 to 85 kWh/t, with the lowest value for block-ice and the highest for flake-ice. If plants are not properly managed, energy consumption can become much higher.

Four ice plants in Tanzania were tested for energy consumption. All installations were relatively new, and similar regarding capacity, type of compressor, type of refrigerant, refrigeration-flow control and condenser capacity. The figures found were as follows: 86

(ice block), 117, 136 and 178 kWh/t; this is between 31 and 93 kWh/t more than the reference value. Faults were found in all these plants, including improper regulation of expansion valves, heat leakage and the malfunction of pumps and propellers (Anon., 1990).

Comment and discuss the following points:

(a) How long ago did you check the energy consumption in your ice plant?
(b) Taking the industrial electricity costs of your country, calculate the money losses per ton of ice produced.
(c) The influence of the extra energy costs surely reverted on the ice costs (ice that should be utilized to chill fish).
(d) The lack of trained personnel to carry out proper maintenance.

8.5.3.2 External failure costs

These are the costs of defects found after shipment to the buyer or consumer. This type of failure is probably the most costly of all. Due to the commercial implications, it is very difficult to find values of this type of cost, and fishery industries in general are reluctant to admit that they had or may have this type of cost. External failure costs can be generated from minor incidents (e.g., relating to a single package of product) to a catastrophic event involving a product recall, which can be devastating to a company and may result in failure of the firm. They include product failures of which the firm will become aware, and those that remain unknown and will be reflected by a fall in sales.

In the case of external failure, the costs usually exceed all the costs involved till the point where the failure is found, and include the liability for the wrong product and the loss of confidence of the customer, that will in turn reflect in the marketing position of the firm. This affects both internal and external markets.

Fish and fishery products are a very particular and sensitive type of food, and publicized external failures influence fish markets in general, regardless of the type of product, firm involved, country of origin, and nature of the problem. This largely justifies the increasing role of the fish producer associations in the field of safety and quality.

Most of the literature available relating to the external failure costs of food in general, and fishery products in particular, has been produced in USA and Canada. This is the core material to be utilized to develop this point. It does not mean that such costs do not exist in other countries, even if not so well known.

External failure costs may involve or create commercial, political, legal and sometimes diplomatic implications which are very difficult to overcome in practice. However, a deeper knowledge of this type of cost is necessary to improve marketing at home and abroad, and to develop and implement at industry and public level effective cost/benefit safety and quality systems.

(i) External failure costs related to international food and fish trade

A first approach to the magnitude and reasons of the most direct component of external failure costs can be attempted by analysing the Monthly Import Detention List published by the Food and Drug Administration (FDA) of USA.

Table 8.5 indicates the reasons, number of lots and estimated values of FDA detentions of all types of foods imported into the USA in the period January-March 1980.

Table 8.5 helps in ascertaining the relative weight of the different type of reasons for detention and the economic impact in each case. It should be kept in mind that Table 8.5 refers only to mandatory safety reasons and does not include eventual complaints by the importer about FDA-approved shipments due to sub-standard quality. Even though a large proportion of the detentions relate to exporters from developing countries, exporters from developed countries also appear on the list.

Table 8.5

Reasons for Detention, Number of Lots and Estimated Values of FDA Detentions of All Types of Foods Imported into the USA, January-March 1980 (1)

Reason for detention	No. of lots	Value in US$ (1980)	%
1. Filth (2)	245	29 242 807	43.5
2. Mould	96	19 678 040	29.4
3. Pathogenic micro-organisms	371	15 206 886	22.6
4. Decomposed	51	1 467 222	2.2
5. Pesticide residues	71	1 050 221	1.5
6. Aflatoxin	18	494 039	0.7
7. Heavy Metals	7	10 592	0.01
TOTAL	867	67 149 807	

Notes:

(1) Adapted from Ref.(Anon., 1985). Primary source FDA

(2) Insects, rodents, excreta and not elsewhere classified (NEC) sources.

From October 1981 through September 1982, 1 924 shipments of shrimp from a few developing countries (mainly South and Southeast Asian countries), weighing a total of some 19 000 t were detained by the FDA because of contamination with *Salmonella* spp. or because of decomposition. The value of the shrimp losses was estimated, conservatively, at around US$ 42 million (Anon., 1985). It is possible to analyse detentions of fishery products alone, from the FDA monthly detention lists. Details of the reasons and volume of detentions of fishery products imports into the USA from 1 to 31 October 1991 are presented in Table 8.6.

Table 8.6 gives more details on detentions related to fish and fishery products. The corresponding total value of detentions, taking average values of 1990 (US Department of Commerce, 1991), for October 1991 is US$ 11.5 million: that is, about 2.5-3% of the total worth of fish exports to USA goes into detention. However, it is not possible to arrive at a common factor for detention/rejection since there is an automatic detention list; i.e., fishery products coming from a given country or producer are automatically inspected. On the other hand, it is possible for a country included in the automatic detention list to define an average external failure cost as the percentage of the total value detained or rejected. Inclusion in the automatic detention list is not permanent, and with good records a firm or export from a country can be taken off the list.

Detention does not imply automatic rejection, since some of the reasons listed in Table 8.6, particularly No. 4 and 6, may be amended. However, nearly 80% of the total weight detained (Table 8.6), is due to reasons that can hardly be changed. The cost involved in removing a shipment from the detention list also represents an external failure cost.

Table 8.6

Reasons for Detention, Number of Cases and Total Weight of FDA Detentions of Fish and Fishery Products Imported into the USA, 1-31 October 1991 (FDA, 1991)

Reason for detention	No. of cases (1)	% of cases	Total weight (t)	% of total weight
1. Decomposed	91	28.3	1 191.3	41.40
2. Pathogenic micro-organism	63	19.6	660.5	22.90
3. Filth (2)	57	17.7	287.5	10.00
4. Incorrect labelling (3)	43	13.4	305.3	10.60
5. Heavy metals (4)	30	9.3	72.8	2.52
6. Unregistered (5)	26	8.0	274.3	9.51
7. Histamine	6	1.9	69.3	2.41
8. Sulphites	4	1.2	17.9	0.62
9. Worms/nematodes	1	0.3	0.6	0.02
10. Abnormal packaging (6)	1	0.3	0.5	0.02
TOTAL	322	100.0	2 880.0	100.00

Notes:
(1) Some of the lots may have been detained for more than one reason.
(2) Insect, rodents, excreta and NEC sources.
(3) Include false, misleading, incomplete and labelling not in English.
(4) In all cases, mercury (Hg).
(5) Unregistered (LACF) manufacturer, and unfilled (LACF) procedure.
(6) Abnormal/damaged cans/containers.

A quick comparison of Tables 8.5 and 8.6 shows that there is a tendency to increase the number of detentions rather than the contrary. The average monthly number of lots of all the food products detained in January-March 1980 was 290, while in October 1991 more than 300 lots, of fishery products alone, were sent to detention. This in turn is linked to the pressure of US consumers to obtain safer fishery products.

Most of the detentions shown in Tables 8.5 and 8.6, even if transformed into rejections, implied for the company involved a failure cost basically limited to the production cost, transport, insurance and analysis involved (although other costs not easily to account for may be involved, e.g., automatic detention of the next shipment, loss of commercial image, customer lost). However, if the defective lot passes the successive inspection steps and produces a foodborne outbreak at consumer level, the cost can be much higher depending on the seriousness of the outbreak and number of people involved. The total costs of some of the best known botulism outbreaks associated with fishery products are shown in Table 8.7.

Table 8.7
Total Costs of Botulism Associated with US Canned Fish Products (Todd, 1985)

Year	Product	Where eaten	No. of fatal cases	Total costs US$ (1986)
1963	Canned tuna	USA	3	167 300 600
1978	Canned salmon	UK	4	6 277 650 (1)
1982	Canned salmon	Belgium	2	150 181 900

Note:
(1) The economic impact of this incident on the UK fishery industry was estimated at US$ 4 million (Anon., 1985).

Total costs presented in Tables 8.5 and 8.7 may appear very high. However, a search on the seizure levels in developed countries would show commensurable figures. In Italy, the Italian Police ("Carabinieri") participates in about 1 500 seizure cases per year of fish and fishery products. During 1991 the 14 most important cases amounted to the equivalent of about US$ 12 million (Anon., 1992).

Example 8.5 Botulism in Canned Salmon, USA 1982 (Todd, 1985), (Thompson, 1982)

On 5 February 1982, FDA's Rockville headquarters learned that a Belgian couple had been hospitalized with a suspected case of type E botulism, usually associated with fish and seafood. The source (as was confirmed later) was a can of pink salmon packed in Alaska, found in a trash box in the couple's home.

By 7 February the husband died and warnings against eating the brand that caused the incident were broadcast throughout Belgium and also in English to the US Armed Forces in Europe. In the meantime, the code of the can was identified. It corresponded to the first production shift of 24 July 1980 of an Alaskan cannery. FDA had inspected that cannery on 29 July 1980 and had checked production reports at the time dating back to 24 July, no problems having been noted on that date.

On 10 February, an FDA canning expert sent to Belgium reported that the incriminated can had a small punched-in triangular hole, and that bits of salmon still in the can showed many spores when examined under microscope.

By 15 February the company was in the process of recalling the half-pound cans of US-packed salmon. UK health officials advised the public not to consume US canned salmon and to return them to the place of purchase. This followed the discovery of a returned can of salmon with the same punched hole, but packed by another Alaska cannery. The reforming machine utilized by the different packers was the apparent source of the problem.

By 17 February, an FDA engineer was able to duplicate the malfunction that caused the hole at the end of the rim. Some cans were torn by the reformer causing a tiny hole. Those cans were not properly sealed because of the holes. Even though they were then properly cooked and sterilized, bacteria (in this case *Clostridium botulinum*) could enter the hole during the cooling process.

On 18 February FDA issued a press release advising US consumers to return to the place of purchase any 7 3/4 oz cans of salmon, with a suspected hole in the lid. The FDA found 22 defective cans in half a million they examined (0.0044% of defectives).

The survey confirmed that the defect may be common to all the Alaskan canneries that utilize the defective re-forming machine, and that it affected the salmon produced in 1980 and 1981.

On 5 March a programme was agreed upon by the salmon industry and the FDA was to assure the safety of all the half-pound cans of salmon produced in 1980 and 1981. Some 50 million cans were still in storage in Seattle.

By 19 March more than 20 million cans were under recall. Several packers decided to implement the recall of their defective products.

By mid-April 1982, more than 50 million cans of Alaska salmon distributed throughout the world were under recall - almost 20% of the 1980 and 1981 output of the Alaska salmon industry. The total failure costs of this incident was US$ 151 181 900 (see Table 8.5). Discuss the following:

- The importance of the incident; national and international impact
- The development of the events, the steps taken, the process of identification of the reasons of the problem
- The process of recall. Does it exist and is it applied in your country?
- By the time of this incident the HACCP basic approach was applied in the fish canning industry in USA as can be seen from the procedure utilized by FDA to inspect the plant. Could you explain what happened?

(ii) External failure costs related to domestic markets

Evaluation of costs at national level for Canada and the USA based on all available costs for 61 incidents showed that company losses and legal action are much higher than medical/hospitalization expenses, lost income or investigational costs (Todd, 1989c). The average cost for industrial food processing incidents is found to be 70 times higher than the average costs incidents linked to food-service establishments, markets, homes, farms and communities (Todd, 1989b). All data and estimates available seem to indicate that external failure costs at national level are higher than those at international level, even though such failure costs do not necessarily affect directly the industry(ies) involved (see section 8.7).

Costs of external failure related to domestic markets in developing countries are in most cases impossible to estimate, first because even obtaining the relevant data is a very costly process, and the responsible Government branches may not exist, and when they do

they very often have no means of performing their job. In many of the poorest countries there is not enough expertise to produce epidemiological data on a consistent basis.
This situation is at the root of one of the main misunderstandings in the fish trade between developing and developed countries.

For many exporters in developing countries it is very difficult to understand why the situation can be so different in the importing country. If there are no problems with the fish at home why are there problems abroad?

As in developing countries records may be not enough to ascertain the true entity of the external failure costs in domestic markets , the only wise decision is to apply the HACCP procedure (or some HACCP-based effective system). This in turn will revert in an improvement of the situation both on domestic and international markets.

(iii) Legal liability and external failure costs

Two aspects linked to external failure costs deserve additional comment. The first relates to Government regulatory actions when specific regulations have been infringed and charges may be laid. The second relates to the law suits that have been or may be initiated by individuals or companies who believe that a warranty or contract has been broken.

Legal liability can be related, in this context, to both safety (public regulations and eventually contractual agreements) and pure quality aspects (contractual agreements). This type of legal liability is generated by a risk that should be kept at a minimum by the process control system responsible for quality production.

This liability is a very important factor in the production of quality in developed countries, but unfortunately is awarded less importance in developing countries. Depending on country regulations and type of problem, products can be seized, injunctions can be presented, companies and executives fined, licences withdrawn and, in extreme situations, those responsible can be prosecuted and officials imprisoned (Burditt, 1984). Seizure is not usual if the firm responsible voluntarily recalls the unsatisfactory product.

Example 8.6 Criminal Case Involving the Presence of *Salmonella* in Froglegs (Anon., 1976)

A case of severe penalties involved the presence of *Salmonella* in froglegs sold by a Texas Company in 1976. The Company was fined US$ 15 000 and the owner placed on year's probation after paying a personal fine of US$ 10 000.

Discuss the case. Could regulations in your country allow such a situation to develop?

Legal action can be sought by anyone, particularly in developed countries, claiming to have a just cause, whether or not a regulation or code has been violated, or even whether or not the person concerned was ill or injured. In many developing countries such type of rights are seldom utilized or non-existent. This may be "advantageous" for the firm in the domestic market, but it can cause easily problems in foreign markets.

This type of cost may not necessarily be an external failure cost. However, proper legal advice and support are needed at the product development stage in order to prevent, as far as possible, such costs and problems. The firms directly in contact with the final consumer (brands, restaurants, supermarkets) are more at risk than firms trading primary and intermediate products. However, the firms sued may in turn recover losses from suppliers if they can prove that they were not the primary offenders. Companies in developing countries operating in the most profitable field of value-added fishery products should be aware of this additional risk. The Company may decide for a settlement in or out of court. This will depend on the individual circumstances. Large food companies have a special department to deal with such cases. While wanting to avoid as much as possible the negative effects of exposure by the press, they have to defend themselves from injustice. In all cases, sound technical knowledge is necessary, together with proper legal advice.

Example 8.7 Case of Out-of-court Settlement. Label Showing Incorrect Information

In 1977, a large German packing firm of frozen fishery products for the internal and European market was denounced to the authorities by different final consumers because the number of shrimps implied by the external picture on the package of a frozen seafood salad was greater than the actual number of shrimps inside the package. The German fish inspection service made a check at the supermarkets where the products had been purchased, and found that the accusation was basically correct, even though not all the packages presented such characteristics. The incident was not prevalent throughout the production, but only in some lots due to the malfunctioning of a dosing machine. Those lots were recalled. The Company wrote a letter to all the claimants explaining what had happened, apologizing and offering in compensation a box of the incriminated product. No one sued the Company, accusations were withdrawn, and the authorities closed and filed the case.

Discuss the example.

8.5.4 Relation between the PAF costs

The PAF model allows to study the relationship between the three main types of quality costs. In principle, the increase of expenditure in prevention and appraisal costs should decrease the failure costs (external and internal), and there will be a point at which total quality costs will be at their lowest. This general behaviour is qualitatively presented in Figure 8.3. The relationship presented in Figure 8.3 can be also expressed by an equation that represents the variation of total quality costs per unit of product:

$$ct(q) = \Sigma\, cf(q) + \Sigma\, cp(q) + \Sigma\, ca(q) \tag{8.1}$$

where:

$ct(q)$ = total quality costs per unit of product
$\Sigma\, cp(q)$ = summation of all prevention costs per unit of product
$\Sigma\, ca(q)$ = summation of all appraisal costs per unit of product
$\Sigma\, cf(q)$ = summation of all failure costs per unit of product

The basic assumptions of equation (8.1) are:

(i) It should be possible to determine costs as a function of quality level (measure of quality).

(ii) Costs of prevention, and particularly costs of appraisal, grow exponentially with the increase of quality and inversely, failure costs decrease exponentially when quality increases.

The exponential nature of the curve of prevention and appraisal costs in Figure 8.3 is mainly linked to the increase of the appraisal costs (increased number of sampling and analysis), as discussed in example 8.3 (see Figure 8.2). Sometimes the fixed costs (supposed constant for all the qualities) are included in Figure 8.2 to give an indication of the relative weight of quality costs on the total costs of manufacture.

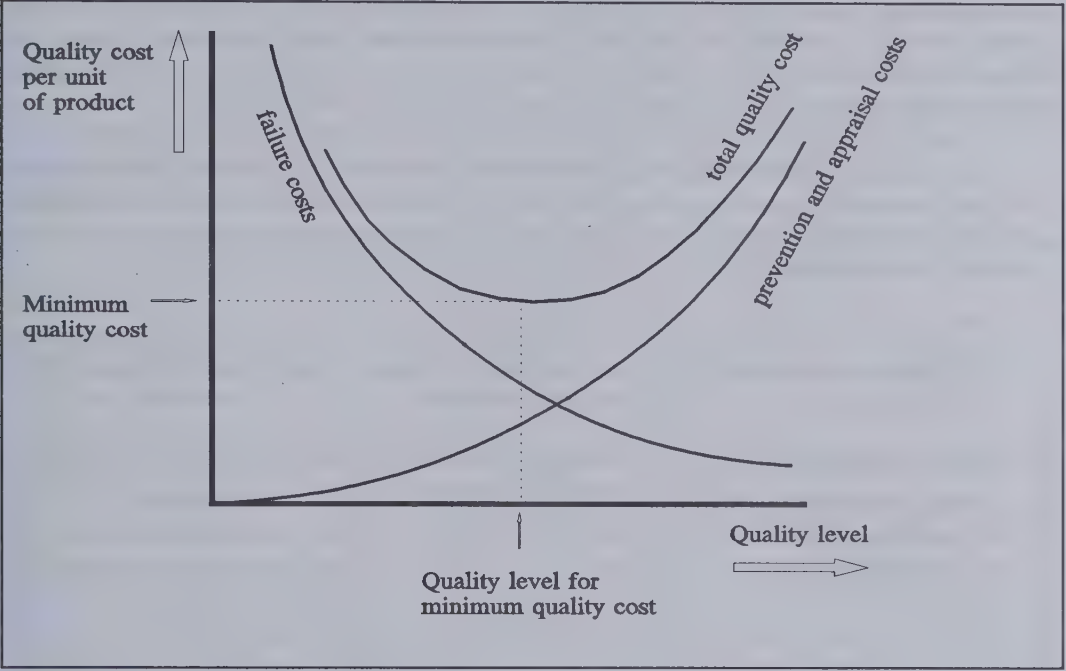


Figure 8.3 Qualitative Variation of Quality Costs according to the PAF Model

The existence of an optimum, and awareness of it, does not mean that a given industry will necessarily work at that optimum. Two large European fishery industries that apply quality economic analysis, have declared to the authors that actual expenditures are above their optimum. Considerations such as net sales, safety, prestige (brand image) and goodwill, may make it advisable or desirable to increase prevention and appraisal costs above the optimum point, as is determined by Figure 8.3.

The application of HACCP and QA can change the actual shape of Figure 8.3. For instance in the design of new plants some of the prevention costs could be eliminated through appropriate design and construction of machinery, premises, equipment and processing lines. This eventually can be also achieved by improvement of procedures within an existing installation, e.g., by eliminating the need of pasteurization in a line of pre-cooked shrimp, as result of the introduction of HACCP and resulting improved shrimp handling. The investment in prevention (fixed costs) can thus reduce the prevention costs (variable costs). This means that a new plant, properly designed and constructed, or a plant where procedures have been improved, could produce a safer and better product at lower cost.

This tendency, identified in other manufacturing industries (Johnston, 1988), is certainly a trend of the modern food and fishery industries. In principle, a given company or processing line (for a specific product) will present three different total quality costs: the actual quality cost (measured directly), the optimum quality cost according to design (see

Figure 8.1), and the optimum operative quality cost, according to Figure 8.3. In general, it can be expected that such quality costs will be related in the following way:

Actual > Operative optimum > Design optimum

whereas the quality achieved will follow just the opposite order. Although it is rather improbable that most of the fishery industry could have this level of information, the concept is useful in that it provides the rationale for improvement, even if optimum values are unknown. At the same time it is underlined that most of the empirical data published relate to actual quality cost.

The relationship between actual quality costs (prevention, appraisal and failure) is also important, because it gives a primary indication of where to direct the efforts to reduce quality costs and increase quality. Table 8.8 gives percentages of actual values of prevention - appraisal - failure costs.

Table 8.8
Prevention - Appraisal - Failure costs, as Percentage of Total Quality Costs in Different Industries

Company/Industrial sector	Prevention: Appraisal: Failure (%)	References
Typical food firm (USA)	5 : 25 : 70	Morgan Anderson (1984)
Uncle Ben's (Australia)	20 : 20 : 60	Hosking (1984)
Chemical products (USA)	14.1 : 23 : 62.9	Harrington (1987)
Average of twelve industrial sectors (USA)	12.5 : 36.7 : 50.8	Harrington (1987)

It is clear from Table 8.8 that the optimum is not necessarily at the intersection of the curve of failure costs with the curve of prevention and appraisal costs (see Figure 8.3). Otherwise failure costs would always be 50% of the total quality costs.

8.5.5 Quality cost indexes

Very often quality costs are analysed with reference to a consistent basis against which relevant comparisons can be made. Although quality cost indexes are not strictly part of the PAF model, some of the indexes utilize costs defined and determined in accordance with it. The basis should represent the business from different viewpoints and be sensitive to management decisions and business changes. The following indexes have been suggested (British Standard Institution, 1981):

(i) Labour base $\frac{\text{Internal failure costs}}{\text{Direct labour}} \times 100$

(ii) Cost base $\frac{\text{Total failure costs}}{\text{Manufacturing costs}} \times 100$

(iii) Sales base $\frac{\text{Total quality costs}}{\text{Net sales}} \times 100$

(iv) Unit base $\frac{\text{Test and inspection costs}}{\text{Unit of production}} \times 100$

(v) Value added base $\frac{\text{Total quality costs}}{\text{Value added}} \times 100$

The sales-based index (iii) seems to be one of the most utilized in practice, although it is recommended to utilize three of them at plant level (British Standard Institution, 1981). Some values of index (iii), expressed as percentages, are shown in Table 8.9.

Table 8.9
Indicative Values of the Quality Costs Index (sales based) in Percentages

Type of Industry	%	Country	Reference
Food industries	2 to 5	Australia	Hosking, 1984
Uncle Ben's	3.6	Australia	Hosking, 1984
Chemical products	4.82	USA	Harrington, 1987
Manufacturing (general)	2.5 to 6	USA	Crosby, 1980
Average of twelve industrial sectors	6.48	USA	Harrington, 1987

According to the literature (Harrington, 1987; Crosby, 1980), a index value (iii) of 6% can be taken as indicative regardless of the product, whereas a value of 2-2.5% indicates that the industry manages quality and quality cost very satisfactorily. The "ideal" value of index (iii) should be zero, which is impossible in practice. Very high values (e.g., 10-20%), and very low values (1% or less) of index (iii) may be found (Hosking, 1984) (Crosby, 1980).

However, extreme values should be analysed with caution as in general very high or very low actual values of index (iii) may indicate a poor quality management and/or costing system.

Although values of index (iii) are widely popular in the fishery industry, very often as a yardstick rather than an actual value, they cannot be determined without a sound economic analysis. Other indexes can be defined: e.g., for the retail food industry where there are unusually high distribution costs, it has been suggested to define an index based on the cost of sales (Crosby, 1980). Values in Table 8.9 are only indicative because comparison with other firms is not always a valid guide to the level of acceptable costs (Sandholm, 1987).

In the fishery industry, often influenced by seasonal variations, the indexes should be chosen appropriately, e.g., on a 12-month basis. Quality cost analysis on a monthly basis could be meaningless and a proper statistical analysis is advised.

8.5.6 Limitations to the PAF model

The PAF model is widely utilized, and it usual to find that large fish and food companies utilize it. A number of observations have been raised, and alternative models proposed. Criticisms on the PAF model include (Porter and Rayner, 1992):

(i) All that is done in a plant is aimed to make a product of a given quality. The risk of focusing in a limited number of costs, deviate for instance from the fact that there is a continuous improvement in quality due both to equipment (hardware) and management and procedures (software). The notion that an optimum quality cost exists may become a static concept, whereas a dynamic situation regarding costs exist in practice.

(ii) The model focuses in cost reduction and ignores positive contribution of improved quality to sales volume and price that improved quality can provided.

(iii) Very often it is difficult to ascertain when a given cost should be considered prevention, appraisal or failure cost. For instance an analysis could fall into any of the three categories depending the purpose and when, along the line, was performed.

This problem is compounded in practice by the difficulty in gathering data on quality costs from current accountancy, and the pursued accuracy of the data gathered (the increase in accuracy could imply also an increase in the cost of performing the quality economic analysis).

(iv) May create the false concept that an additional management function is needed to reduce quality costs and improve quality. Whereas prevention should be just part of good management practices, and management should assume full responsibility for declared product safety and quality (liability). It is not rare to find that sound management improves quality, without increasing prevention costs.

(v) The PAF model seems to be inappropriate to the needs of small and medium-sized firms. This may be due to its complexity, and a more simple approach to quality costs would be needed. However, there may be other reasons, for example that in small firms appraisal costs are assumed as an integral part of production overheads and failure costs are reputed as non-existent. Moreover, and perhaps more relevant, in this case the owner is usually the plant manager, and therefore prevention of mistakes and waste is considered a basic task of management ("The eye of a master does more work than both his hands").

Some of the above points have been discussed. The reader should be aware of the PAF model drawbacks discussed in order to adjust it to practical situations. Other models, e.g., "tangible and intangible costs" (Juran *et al.*, 1975), process cost models (costs of conformance and of non-conformance of a process) and cost-benefit models (Porter and Rayner, 1992), have been suggested.

Nevertheless, in the authors' opinion such models do not address all the observations (in particular those concerning the small and medium sized firms) and are not yet widely applied. The PAF model, with due considerations, can still render a service to most of the fishery industry, at least by starting a necessary conceptual and practical discussion within the firms on the subject of quality costs.

8.6 The Cost of Applying HACCP

The worldwide trend to HACCP and HACCP-based systems application in the fish process industry has raised the question of the cost to implement HACCP in existing plants. In turn, the industry expects that this investment to be recovered and produce a profit. In the USA, the Food and Drug Administration (FDA) has published the result of two estimations on the investment necessary to apply HACCP (US FDA, Federal Register 28 January 1994). One estimation was conducted by FDA, and the other by an independent consultant firm. Results are shown in Table 8.10.

The cost of implementing HACCP, and the possibility to recover the investment and profit, will depend in practice on a number of variables. First, it depends on how far the existing facilities and procedures are from a basic HACCP condition. The farther, the more costly. The number of hazards to be included in the system will also influence the final cost (e.g., a system including only public health hazards will cost less than a system aimed at including public health, economic fraud, spoilage and hygiene hazards). The final cost will also depend on such factors as: the type of product, current and prospective markets requirements, current appraisal costs, awareness of actual failure costs, current regulations, availability of trained people and proper advice.

Table 8.10

Estimations of Investment (in US$) Necessary to Apply HACCP to the Fishery Industry (US FDA, Federal Register 28 January 1994)

Type of firm	FDA Estimation	Independent estimation
Most of the firms (start-up costs)	1 000-5 000	
Some firms	≥ 20 000	
Small plants (1st year)		24 000
Small plants (2nd year)		14 700
Large plants (1st year)		23 400
Large plants (2nd year)		15 700
Importers	8 690	
Repackers & warehouses	8 900	
Foreign processors (1) (average initial costs)	11 815	
Foreign processors (1) (average recurring costs)	5 915	

Note:

(1) Refers to fish processing plants in foreign countries that export to the USA under proposed FDA regulations on HACCP

Costs of Table 8.10 vary widely, from US$ 1 000 to US$ 39 000 or more, due to the actual distribution in the hygienic and sanitary conditions of the fishery industry, and can be taken only as indicative. Table 8.10 gives the following useful indications:

(i) The cost of implementing HACCP seems largely independent on the production volume. This may be because some of the costs involved are independent of the size of the plant, e.g., a temperature indicator and recorder will cost the same for a 10 m^3 than for a 100 m^3 cold storage room. It may be due also to the fact that large plants, in general, are nearer to a basic HACCP condition than small plants.

(ii) HACCP implementation will take more than one year.

(iii) It is foreseen that plants exporting to the US market will have average costs above those expected for US firms. In addition, fish importers will have a cost increase.

Costs listed in Table 8.10 may appear below than those expected by the industry. In one publication (US FDA, Federal Register 28 January 1994) it is recognized that a number of additional costs need further analysis. Costs associated with the retrofit of existing plants, necessary for the proper operation of HACCP (e.g., a new freezer, a new water supply line) are not included in costs of Table 8.10.

Other costs not included in Table 8.10 are: training employees, creating the HACCP plan, taking corrective actions to respond to critical deviations, recall (short term), record keeping burden, ensuring that some particular equipment is achieving the desired result (e.g., cooking, pasteurization and cooling) and restricting catch in certain areas and seasons if processors (and Government) find it necessary (e.g., for ciguatera).

Industry could find actual costs to implement HACCP much higher than those listed in Table 8.10, particularly in cases where serious flaws in premises, machinery or processing lines exist. An in depth quality economic analysis would be necessary to asses in practice the actual costs of implementing HACCP and its economic advantage. Some companies may reach the extreme conclusion that it will be cheaper and more profitable to construct a new plant and scrap the old, than to refit it.

In many cases, particularly in those where proper GMP and Codes of Practice are already followed, it will only imply additional measuring equipment (e.g., temperature indicator and recorders), increased monitoring and record-keeping and perhaps minor improvements in fish handling, processing and storage.

Implementation of ISO 9000 series standards (voluntary) should be seen as a further step after application of HACCP or HACCP-based systems (now mandatory in many countries), and it will involve a cost. Firms could seek implementation of the ISO 9000 series certification as a way to improve their market position. Until now only a limited number of fishery industries (all in developed countries) have attempted or obtained the ISO 9000 series certification.

8.7 Social and Political Costs of the Lack of Food Safety and Quality

Most of the external failure cost due to food (not only fish) unfit for human consumption is hidden and unknown. It is widespread, distributed among individuals, Government (health assistance services), insurance companies, and employers (of affected staff).

8.7.1 Epidemiological data

The main reason for the situation discussed above, even in developed countries, is the lack of sufficient and consistent epidemiological data. The chain to ascertain the linkage between a food incident and the food vehicle responsible for it, is as follows:

Food incident
↓
Food incident reported
↓
Etiological agent identified
↓
Food vehicle identified
↓
Place where the food was contaminated/mishandled

In many countries, particularly developing countries, there is no structure to gather information and investigate food incidents, or if the structure exists formally, it does not have the resources and facilities (e.g., human, financial, laboratories) to perform its duties. Even in the comparatively few countries which have a reporting system, severe under-reporting is suspected. According to Mossel (1982) only about 1% of the total number of incidents is reported. Table 8.11 lists some of the epidemiological data available regarding the incidence of fish and fishery products in ascertained foodborne disease outbreaks.

Values and percentages presented in Table 8.11 depend on each case of a number of factors, for instance on the characteristics of existing system of data collection (e.g., promptness to collect and analyse the suspected food, possibility to perform the right analysis), on consumer habits (type and amount of fishery products consumed), on awareness of the physician and the victim on the etiological role of foods, on period chosen to group the data, and on more banal aspects such as if comparisons are based on outbreaks, cases or incidents. In general only in a fraction of reported incidents has it been possible to identify the etiological agent responsible for the outbreak, and in an even smaller fraction to identify without doubt the food that acted as the vehicle of the etiological agent. For instance, the number of food outbreaks reported to the US Centers for Disease Control (CDC) in the period 1978-1982 were 14 340 cases, of which in only 8 031 cases (56%) was it possible to identify the etiological agent (Todd, 1989a).

A review study (Bryan, 1988) of the US foodborne surveillance data for the years 1977 through 1984 showed that in only 1 586 cases were the food vehicles identified. For those 1 586 cases, fish and fishery products accounted for 24.8% of total cases identified, which presumably puts fish in the USA as the first food category at risk (meat 23.2%, poultry 9.8%, salads 8.8%). Figures in Table 8.11 (from Bean and Griffin, 1990) make fish responsible for 20.3% of the cases, and a study by the National Fisheries Institute (NFI), for the period 1973-1987 on 162 951 cases reported to the Centers for Disease Control, found that fish and fishery products were only responsible for 5% of the cases (2.2% finfish and 2.8% shellfish) (NFI, 1992). Therefore, data on Table 8.11 are presented only to identify whether or not a general trend may exist, or if analysed case by case in detail, to find areas of concern for public health authorities and industry. It is clear from the previous paragraph that information such as given in Table 8.11 should be carefully evaluated. In actual markets, seafood is in competition with other foods and such data may be used to commercial purpose. However, it is clear that fish and fishery products (as other foods) have an etiological role in food incidents.

Table 8.11
Epidemiological Data on the Importance of Fish and Fishery Products as the Ascertained Vehicle of Foodborne Disease Outbreaks in the Period 1985-89 (1)(2)

Country	Total number of outbreaks (3)	Outbreaks due to fish and fishery products	Incidence of fish and fishery products (%)
Albania	41	1	2.5
Belgium	28	3	10.7
Canada (4)	1 692 (13)	148 (13)	8.7 (13)
Croatia (5)	7 053	373	5.3
Cuba (6)	1 276	172	13.5
Denmark	184 (13)	31 (13)	16.8 (13)
Finland	176	32	18.8
France	357	35	9.8
Germany (F.R.) (7)	183	8	4.4
Germany (F.R.) (8)	42 (13)	4 (13)	9.5 (13)
German (Dem.Rep.)	477	13	2.7
Japan (9)	3 742	1 316 (14)	35.2 (14)
Netherlands	767	42	5.5
Portugal (10)	105	10	9.5
Spain	2 684	136	5
Sweden	89	9	10.1
UK (England and Wales) (11)	438	9	2
UK (Scotland)	1 089	76	7
USA (12)	3 699 (13)	753 (13)	20.3 (13)

Notes:

(1) Data from 5th Report (1985-1989) WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe, Berlin, 1992 (unless other reference specified).
(2) Only ascertained cases. Data do not include "not identified/unknown" outbreaks /cases /incidents.
(3) Include all the reported outbreaks/incidents where the food vehicle was identified.
(4) Data for 1982-83, Todd (1989 b).
(5) Data for 1986-92, Razen and Katuzin-Razen (1994).
(6) Data for 1984-88, Grillo Rodriguez (1989).
(7) Data do not include incidents caused by *C. botulinum*.
(8) Data on incidents caused by *C. botulinum*.
(9) Data for 1989-93, Toyufuku (1994).
(10) Data for 1987-89.
(11) Data for 1986-88.
(12) Data for 1973-87, Bean and Griffin (1990).
(13) Data reported as "incidents". An incident is an outbreak or a single case. An outbreak is an incident involving 2 or more persons. Case, single case or sporadic case, is an incident in which only one person is involved.
(14) Only includes outbreaks due to *V. parahaemolyticus* and food poisoning due to puffer fish.

8.7.2 Estimated costs

Consumers and Governments, particularly in developed countries, are becoming increasingly concerned about the implications of the etiological role of foods. This is due mainly to the following reasons: the steady increase of health service costs, the trend to avoid tax increases to pay for public health assistance (and the reduction in public health expenditure), and the increased awareness on food safety and quality and nutrition.

For developing countries there is little information available but actual costs may be severe. For instance, the World Health Organization (WHO) has estimated that in Pakistan 4 out of 10 deaths are due to waterborne and foodborne disease. As Todd (1989, a) stated: "Foodborne disease is increasingly being recognized as a major cause of morbidity in both industrialized and developing countries, and also mortality in the latter, but the full extent of the social and economic impact is hard to measure".

At the current state of knowledge most of the cost estimations are little more than guesses based on extrapolations of epidemiological data, as discussed in Table 8.11, and costs of ascertained incidents. However, this is a field of knowledge in quick expansion, and a number of studies proposing new models and ways to analyse the problem are appearing in the literature (see for instance Caswell, 1991 and Sockett, 1991).

Table 8.12 shows the findings of a study on the total costs of foodborne disease in the USA. This study was based on the comparative analysis of five different and independent estimates and on available data of known cases. The costs detailed in Table 8.12 integrate: costs of illness, death and the amount of business losses.

There is evidence that costs in developed countries for the same type of etiological agent are of a similar order. For instance in Canada, cases of acute bacterial foodborne illnesses were estimated at 1 million per year, and total costs around US$ 1 100 million

(Todd, 1989c). However, it is not possible to link directly the estimates of Table 8.12 and the existing epidemiological data analysed in Table 8.11. It is an error to extrapolate such results and assume that fish and fishery products are responsible for 20.3% of the cases and estimated costs indicated in Table 8.12.

Table 8.12
Preliminary Estimates of Annual Number of Cases and Total Costs (illness, death and business lost) of Foodborne Disease in the USA (Todd, 1989a)

Etiological agent	No. of cases	Total costs US$ million (1)	%
1. Total bacterias (2)	5 500 510	6 777	85.8
2. Total parasites (3)	1 486 000	625	7.9
3. Total viruses	216 000	337	4.3
4. Seafood toxins	58 260	125	1.6
5. Chemical poisons	96 000	29	0.4
6. Plant poisons	7 000	4	0.05
Total known	7 364 200	7 897	100.0
Total unknown	5 217 000	529	
TOTAL (4)	12 581 000	8 426	

Notes:

(1) US$ of 1988 (not clearly stated in the reference).

(2) The most important are *Salmonella spp.* (not *S. typhi*) with more than 40% of the known cases, and more than 50% of the total known costs

(3) Includes 1 000 estimated cases of fish parasites.

(4) Other estimates are in the range of 5 to 19.8 million cases per year.

Example 8.8 Estimate the Economic Impact in USA of Fish as Vehicle of Etiological Agents

A first crude approach could be to take the figures provided by the NFI (1992), in this case 5% of US$ 7 897 million would be US$ 394.85 million. An alternative approach could be the following:

(a) Estimate the yearly average number of cases due fish and fishery products.

The total number of cases (X_t) will be:

$$X_t = x_b + x_p + x_v + x_{st} \tag{8.2}$$

where:

x_b = number of cases due to bacteria

x_p = number of cases due to parasites
x_v = number of cases due to virus
x_{st} = number of cases due to seafood toxins.

From Bryan (1988), in the ascertained cases of bacterias, fish was identified as a vehicle in 3.33% of the cases. If on average the proportion holds (see Table 8.12):

$$x_b = 0.033 \times 5\,500\,510 = 181\,500 \text{ cases}$$

From Table 8.12: $x_p = 1\,000$ cases, and $x_{st} = 58\,260$ cases

From Bryan (1988) viruses in average represent 24% of the cases associated with fish as the vehicle; this means:

$$x_v = 0.24 \times X_t$$

Replacing in (8.2):

$$X_t = 181\,500 + 1\,000 + 0.24 \times X_t + 58\,260$$

Solving for X_t and x_v results in:

$$X_t = 316\,789 \text{ cases} \quad \text{and} \quad x_v = 76\,029 \text{ cases}$$

From the values obtained, and average costs for each type of etiological agent from Table 8.12, Table 8.13 is obtained.

Table 8.13
Total Estimated Costs per Year of Cases due to Fish and Fishery Products as the Vehicle of Etiological Agents in the USA (1)

Etiological agent	No. of cases	Cost US$ (2)
Bacteria	181 500	223
Parasites	1 000	0.4
Viruses	76 029	118
Seafood toxins	58 260	125
Total (fish)	316 789	466.4
% Grand Total	4.3 (3)	5.9 (3)

Notes:
(1) Based on data of Bryan (1988) and Todd (1989a).
(2) In millions of US$ of 1988.
(3) Taken as basis for the estimation only the total known cases of Table 8.12.

Results like those of Table 8.13 are highly speculative, serve only to identify trends and to have an order of magnitude of the problem. Comments to Table 8.13 could be as follows:

(a) The impact of the results shown in Table 8.13 may be measured against the total value of fish traded in the USA, estimated in US$ 6 000 million per year. In this case the economic impact would be about 7.8% of the total value of fish traded.

(b) The percentage in the total number of cases differs from those in Table 8.11, and is even lower than the estimate of NFI. This is because Table 8.12 introduces a model of how the results may be extrapolated, and because during the calculations assumptions (based on existing data) were made.

A model is essential to produce this type of estimate because, for example, there is not the same type of availability and frequency of consumption of each kind of food within a country. Moreover, there are some types of seafood consumption (e.g., raw oysters) that are very risky, produce a relatively large number of cases and are relatively easy to identify (since consumers and physicians are very aware of the risk). However, the consumption of raw oysters is very limited, and cannot be compared with other types of foods (e.g., hamburgers or eggs). The same holds for parasites and seafood toxins. It has also been recognized that outbreaks related to fish and fishery products frequently involve few people (Bryan, 1988). Nevertheless, the model and assumptions used here may be not completely correct (e.g., the number of cases due to viruses included in Table 8.13 could be above the actual cases) and a more specific model would be advisable.

(c) Percentage of total cases would not be the same as percentage of costs, since each etiological agent has its own average cost. Some efforts to improve the situation could be most cost-effective than others.

This kind of analysis reveals that further studies are necessary in this field in order to ascertain the true costs of hidden external failure of fish and fishery products, even in cases when epidemiological information is available. Discuss:

(i) The results presented in Table 8.13. Using the information included in the basic references (Bryan 1988; and Todd 1989a) do you think it may be possible to obtain different results?

(ii) Do you think it would be possible to construct a table like 8.13 for your country? If not, which kind of information is missing?

(iii) Why may large differences exist between countries regarding the relative importance of etiological agents and costs? Why may there be such a large difference (see Table 8.11) between UK (England and Wales) and Denmark and Finland?

The lack of documented information in developing countries by no means implies an absence of the problem, and absence of costs. An Indian research study on the economic impact of a foodborne disease outbreak due to *Staphylococcus aureus*, suggested that, despite the fact that the absolute values involved were very different, the relative costs (when comparing with the *per caput* income) are higher in India than in USA (Sudhakar *et al.*, 1988). Further research in this sense is also needed.

8.7.3 Places where food was contaminated/mishandled

Data such as those included in Tables 8.11 and 8.12 should be complemented with information as to where incriminated food was contaminated or mishandled. Unfortunately, this type of information is even scarcer than that on etiological agents and type of food vehicle. Some of the available data are listed in Table 8.14.

Table 8.14
Foodborne Disease Outbreaks by Place where Food was Contaminated/mishandled, 1985-89 (1)

Place	Belgium	Denmark	Netherlands	Sweden	Scotland
Lake/sea/ship	1	-	-	3	-
Restaurant	1	43	319 (2)	26	118
Retail outlet	1	14	-	1	30
School/kindergarten	2	16	-	2	8
Mass catering	7	21	-	3	30 (4)
Private home	1	75	33	9	123
Food processing establishment	3	12	4 (3)	3	7
Ambulant service	-	2	-	-	1
Imported	-	1	-	-	-
Other	-	3	28	7	44
Total known	16	187	384	54	361
Unknown	16	50	394	59	653
Grand total	32	237	778	113	1 014

Notes:

(1) Data from the 5th Report (1985-1989) WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe, Berlin, 1992
(2) Includes cafeterias
(3) Small food business
(4) Includes factory canteens and other workplaces, military camps, oil rigs and prisons

The most interesting point of Table 8.14 is that contamination and mishandling of food in food processing establishments occurred in most of the cases in comparatively low percentages. There are no published data on the incidence of fish processing plants within the percentage due to food processing establishments.

In general most of the outbreaks were generated by contamination and mishandling in restaurants, catering and private homes. In this sense the situation may be considered damaging to the fishery industry (or other food industries), since a publicized outbreak due to fish will affect the economics of the fishery industry, even if they are not responsible (and liable) for the outbreak. However, a number of aspects should be taken into account. Even if information as that of Table 8.14 downgrades the possible responsibility of the industry, absolute figures could still be very high, particularly if the possible share of unknown cases and under-reporting are taken into account.

This point discusses possible involvement of the fish (and food) processing industry. Positive cases of food processing establishments responsible for contamination or mishandling as indicated in Table 8.14 undoubtedly lead to external failure costs, as those discussed in section 8.5.3.2. Figures in Table 8.14 could be taken as indicative of a trend (e.g., that industries are responsible only for a limited percentage of the places where food was contaminated/mishandled), but cannot be generalized and extended to other conditions. Some hygienic and safety principles remain valid regardless of the data, e.g., the existence of contaminated food increase the risk of cross-contamination (with the same or other food).

As a general conclusion of section 8.7 it could be said that hidden costs of lack of food safety are certainly very high. However, the responsibility of the fish (and food) industry, on such hidden costs may be comparatively low.

General application of HACCP will certainly reduce even further the liability (identified failure costs) and possible responsibility on hidden costs of the fishery industry due to the lack of safety of fishery products. It is also advisable that the fishery industry take a more active role regarding safety and quality, because this concerns its own marketing interest. Common moves (e.g., fish processors associations) are largely necessary. However, a substantial reduction in the total number of incidents, and hence in the total hidden costs, would be possible only with widespread application of HACCP and HACCP-based systems, to all types of food and to all the food chain, in particular restaurants, catering and private homes.

Nevertheless, it is evident that zero defect, and hence zero risk, is economically impossible (see Figure 8.2). Zero defect, as already pointed out, is also an unrealistic objective. "No human activity including eating and drinking is or can ever be exempt of all hazards. Consequently, in essence, a zero risk situation cannot exist" (Mossel, 1989).

8.8 Environmental and Political Factors that may Contribute to the Costs of the Lack of Safety and Quality

Section 8.7 discussed the possible costs associated with lack of safety and quality not included specifically in external failure costs of the product. However, as discussed in section 8.2, quality could have a very wide meaning today and encompass other aspects not directly linked with the product. Political, environmental and ecology factors may contribute to creating situations leading to costs that may eventually qualify as quality costs.

8.8.1 Political factors

Lack of safety and quality of food products, when publicized, affect the public opinion, which in turn generates a political pressure. When people are made aware of food outbreaks, or just informed about trends or average figures, a question frequently asked is:

What are the authorities doing abou it?

There are two different aspects, one strictly linked to law and regulations, what are the authorities supposed to do, and which are the Government liabilities (for not doing, or even despite doing)? The second aspect is political, and relates to the relative interest paid by the public administration on matters of food safety, public health and related areas (e.g., public health share of public funds). This situation varies widely from country to country, as well as perception of public liability and political responsibility. In some countries the existence of public health officers and food and fish inspectors, empowered as sanitary police, makes Government fully, or at least co-responsible, for outbreaks. Very often this responsibility is seen by ordinary people as greater than the responsibility of the police force regarding crime, or traffic police regarding road accidents.

However, the situation is changing. Even affluent countries do not have enough resources to cover the cost of inspecting and testing all the food produced. In this context alternatives like the application of HACCP and HACCP-based systems, quality assurance methods and the concept of "due diligence" have been developed.

Although official inspection pressure (e.g., in plant inspection, mandatory sampling and analysis) could eventually be reduced (reduction of appraisal costs), as a result of HACCP-based systems, and rules made more straightforward and specific (deregulation), all liability will lie with the producer, regardless of the existence of a specific sanitary police, and even regardless of the issuance of an official certificate covering a given lot. This means in practice an increase of failure costs (costs of implementing HACCP at plant level as discussed in section 8.6). This is of particular importance for exporters in developing countries, because in many cases "letters of agreement" between countries on fish exports, make them directly and fully liable both in the country of origin and in the importing country, despite official fish inspection certificates that may be issued by both countries. This is particularly serious for countries where there is no proper system to investigate food incidents (see section 8.7.1) and where in consequence food producers (at any level) may feel not liable.

It is difficult to foresee how the full system will evolve. However, it will imply new costs (and new market opportunities). Firms in doubt will have to take specific insurance to cover possible liabilities due to a lack of safety and quality of their products (prevention cost or failure cost?). If claims to insurance companies increase due to food incidents (as may happen in developed countries) insurance costs will also increase. This also makes common action necessary on the part of the fishery industry. Although public administration can attempt to transfer to the private the full liability of food incidents (and there is hardly any alternative, with the current trend of reduction of public administration), political responsibility will remain. It is in practice unavoidable, because politics involves taking decisions in the presence of strong uncertainties, and very often to search for a balance between desirable but in practice opposed objectives.

Example 8.9 Rancid fish - Resignation by Minister

Extracted from The Daily Telegraph, 25 September 1985:

"Tins of unfit tuna have cost Mr."X"[1], Canada's Minister of Fisheries, his job.

He resigned after the State television network disclosed that he allowed nearly 1 million tins of fish to be sent for sale in shops, although Ministry inspectors had judged it unfit for human consumption. In a visual assessment they classed it as "rancid".

Mr."X"[1] allowed it to be sold after politicians in New Brunswick put pressure on him by saying the canner[1], of St. Andrews, would be forced to close down and 400 jobs would be lost. The Minister called for a second study by the "Research and Publicity Council", which also found the tuna unfit but he did nothing to recall it until the Canadian Broadcasting Corporation made the facts public. Mr."X" insisted the fish had not been a health problem, but the Opposition leader and former Prime Minister, Mr."Y"[1], said hundreds of people had contacted his party and reported that the fish had made them sick.

Mr."Z", Prime Minister, said it was "pretty ... obvious" the tuna should not have been permitted to be sold in shops."

The tuna was also rejected by the Department of Defense and by Canada's Coordinator for Famine Relief for possible donation to Ethiopia (New York Times and Toronto Globe and Mail, 24 September 1985). Discuss the following:

(i) Final external failure costs for the firm. The name of the firm was reported in the newspaper articles.

(ii) What do you think about the statement that rancid fish poses no health problems?

(iii) What do you think of re-sampling as a general technique to argue about already ascertained positive results?

(iv) What do you think the public opinion rate as more important, a social problem (close down of a factory and jobs lost) or a safety /quality problem ?

(v) The Canadian reaction should be rated very positively; it indicates civil and democratic behaviour.

The previous example is illuminating regarding the risks run by a firm when it attempts to solve safety and quality problems through political decisions (in this case trying to avoid failure costs). However, the most common problem is probably the attempt to twist or circumvent existing quality and safety regulations through illicit methods (e.g., bribing to obtain a public health certificate).

Corruption is not a new phenomenon, and is present to some degree in all societies. According to a World Bank report (Gould and Amaro-Reyes, 1983) corruption occurrence in developing countries has raised substantial concern and "much corruption in developing countries takes place in the import-export sector of their economies".

Although corruption seems to bring some economic advantage to a single firm in the short term (e.g., "help cut bureaucratic red tape and overcome rigidity by expediting transactions that would otherwise be delayed") and gives the impression of "transferring decision-making power from the public to the private" (Gould and Amaro-Reyes, 1983), it is noxious for the whole sector, and certainly noxious in the middle and long term even to the individual firm. "According to much of the data examined .... corruption has a deleterious, often devastating, effect on administrative performance and economic and political development" (Gould and Amaro-Reyes, 1983).

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[1] Information not relevant to the case

Usually a bribe is a cost that will reduce profit, although in some cases it may appear as the "entrance fee" that makes profit possible. However, in the attempt to recover the cost (or the "fee") and increase profit, quality is very often reduced (as can be seen from Figures 8.1 or 8.3 this will be a self-defeating strategy). The obtention of a fish inspection certificate for export (or at the entrance point), with fake values, does not mean that the failure cost will not be produced anyway, when the lot arrives at destination.

Although it is not possible to make a direct or indirect evaluation of the costs produced by this type of situation, rejections by import countries could give an idea, particularly in cases where large percentages are involved. To the values already discussed in section 8.5.3.2, related to failure costs in international trade, it can be added for instance, that in Canada in the year (1 April 1989 to 31 March 1990) 9.8% (6 225 t) of total frozen fish and 6.2% (1 965 t) of canned fish imports were rejected, reasons for rejection being "decomposed/tainted" fish in 70.7% of the cases (Emberley, 1991).

Although it cannot be said that all the rejection cases fall into this type of condition, it seems obvious that in cases where country export certificates are awarded without proper care, it will create suspicion in the importing country. If repetitive, this type of situation leads in many countries to automatic detention of imports from the incriminated company, or even from all the shipments from a given country. To be in automatic detention, implies an additional (failure) cost.

Further, corruption undermines the credibility and legitimacy of public institutions and creates an atmosphere of distrust at all the levels of public bureaucracies and discourages appropriate training of civil servants (Gould and Amaro-Reyes, 1983). The implementation of HACCP, by reducing inspection pressure and red tape may contribute to reduce corruption. It can be reduced further, by the action of industry associations that look into medium and long term development.

8.8.2 Environmental and ecology factors

There is a worldwide growing awareness on environment and ecology. For many centuries man has treated the Earth as an infinite source of resources and an infinite sink of waste. Now it is clear that the Earth is finite in both senses. Part of this situation, in particular the consequences of overfishing, are well known to the fishery industry, and economic implications and basic management were discussed in section 5.5.

The fishery industry that depends largely on a natural resource, and that has suffered and is suffering from pollution created by others (e.g., heavy metals, pesticides contamination and oil spillage), has just begun to understand that its production should be adequate to the environment. Environmental concerns are mainly linked with the effects of actual or possible levels of air, water and earth pollution. Pollution is not a new phenomenon but in the past was limited to certain geographical areas and the overall self-regenerating capacity of Earth was largely intact. Today, pollution phenomena have transnational and even global effects, and it is known that environment has a limited capacity of self-regeneration, in some cases already exceeded.

Environmental and ecological concepts may be linked to the concept of quality (in general "quality of life", see section 8.2 (b)) in the way problems generated by a wrong use of environment and live resources, can affect mankind, in the short, medium or long term. In particular, ecology concerns, are aimed at the conservation of biodiversity and endangered species, since reduction in the number of existing species could also affect mankind.

Quality linked to environment and ecology is "intangible" in the sense that it is not directly linked to the product or associated services (e.g., it is not known if a can of tuna was produced by a company that treat its wastes or not). It is also "intangible" in other senses, for instance, certain global aspects cannot be experimentally tested (e.g., the Earth cannot be moved to a point where the biosphere is no longer in a position to self-recover from massive carbon dioxide emissions and restore it to previous conditions). Possible effects can be assesed, in some cases, only through computer simulation.

As environmental and ecological problems are already too many, it is not enough that consumers, producers, or Governments, be merely aware of them to define an operative "quality". It should be recognized that a given environmental or ecology aspect is relevant, that it can be linked to certain types of product or activity, and effective ways (formal or informal) decided on how to change the situation. This is in practice a cumbersome procedure open to discretionary decisions. However, once decided, the characteristic chosen becomes integral part of the "quality" concept, and therefore liable to generate accountable failure costs at the firm level, in the sense discussed in section 8.5.3.

However, a portion of the costs connected with use (and eventually misuse) of environment and live resources, are hidden costs since they are not usually taken into account in ordinary economic analysis. A typical case linked to the fishery industry is effluent treatment. In a study conducted in 1980 on twelve Australian fish processing plants, nine discharged the untreated effluents into the town sewerage, and three the untreated effluents into the sea, a nearby river and the harbour (Dunsmore *et al.*, 1983). In the case of disposal to the town sewerage, the costs of treatment were transferred to the town, and in the case of use of natural sinks to the environment. Today the picture has changed and is changing also in the developing world where several countries (e.g., Thailand and Venezuela) are in the process of enforcing specific regulations on effluents from the fishery industry.

In addition to waste treatment there are other aspects that are already or may become important in the near future in relation to the perceived final quality of the product. The following can be noted: protection of endangered species, type of fishing gear utilized to catch the fish (particularly in relationship to its selectivity), amount of water used during processing (clean production), use of no-waste fish capture and processing technologies, air and water pollution and packaging (biodegradability and use of non-critical materials).

One of the most relevant environmental problems, that would imply additional costs, is emission of carbon dioxide. Carbon dioxide is linked to the global greenhouse effect that according to most experts is and will be responsible for undesirable weather changes. Some countries are thinking of imposing a "carbon tax" proportional to emissions and other schemes are also being studied. If current discussions at the UN Conference on Trade and Development (UNCTAD) are successful, a worldwide system of carbon dioxide "emission entitlements", that could be traded at national and international markets, would be implemented (probably not before the year 2000).

"Emission entitlements" would be awarded to the countries proportionally to the number of inhabitants. Each company would have a share. However, if emissions would like to be increased (e.g., by addition of new dryers) the company would have to buy additional "emission entitlements". If emissions are reduced (e.g., incorporating more efficient engines) the company will be in position to sell the "emission entitlements". This system is in part based on the fact that in the USA there is already trade in Government permits to control emissions of sulphur dioxide, a cause of acid rain.

In the field of ecology, environmental associations have already found that they can present their cases to courts in developed countries (particularly in the USA), and that in this way they could economically damage the supposed culprits, and thus force them to behave in a given way. Simultaneously consumers are convinced, by the same associations, that a mark on the package (e.g., "dolphin friendly tuna") is part of the "quality" of the product, a type of quality the supposed "culprit" product has not.

Regardless of the merits of the objective pursued, the procedure described above has become a very debatable methodology, quite different for instance, from the CFC Montreal Protocol or the agreements on "emission entitlements". It has already received criticism both from the industrial and the ecology side. Moreover, there is the risk that this type of legal action may be utilized (or promoted) as a non-tariff barrier or an unfair commercial tool, and therefore lead to international controversy, eventual commercial retortion and trade impairment, without fully achieving the pursued objectives.

Although the final system (or systems) that Governments will follow is (are) not yet decided, "clean" and less wasteful companies will have comparative advantages by having reduced production costs and a better public image (marketing). It would be a negative attitude to dismiss environmental and ecological issues as merely bothersome or problematic. Even if innovative techniques for improving catching, processing or marketing are accompanied by procedural constraints, it should be understood that this new situation will offer new opportunities for those aware of its potential.

APPENDIX A
EXAMPLES OF FISH MARKET STUDIES

Markets have to be researched because each one is different and shaped by different forces (economic, political, demographic, international and social). It is not possible to generalize about customers or to take short cuts by using information from one market to take decisions in another. Since markets change, and there are even changes in the same market, information has to be updated as circumstances change.

The main variable influencing market demand is the price of the goods or service, but there are other relevant factors, such as: consumer tastes and preferences, consumer income, price of related items, consumer expectations. A knowledge of how changes in these variables can modify the quantities of goods sold is very important for the enterprise and the producer, and an essential aspect of demand analysis. The expression used to describe how quantity demanded responds to a change in one demand variable is **Elasticity of Demand**. Price elasticity shows the sensitivity of product demand to price changes. When elasticity is less than 1, demand is inelastic. When elasticity is greater than 1, demand is elastic.

One strategic application of these concepts will be described: the decision to mechanize or completely automate a process depends partly on the elasticity of demand for the product concerned. Assuming the main reason for mechanization is to reduce production costs (and not, for example, to avoid labour disputes or improve safety), it is logical that some of the savings be passed on to consumers in order to increase demand, which will in turn allow the maximum use of expensive equipment. If demand is elastic, this policy would be the obvious choice. An inelastic demand would make this policy less attractive, as any increase in volume resulting from reduction in price, will be relatively small.

Similarly, the income elasticity of demand measures the relative effect of a change in income on quantity demanded. Goods with positive elasticity are "normal", while those with negative income elasticity are "inferior". Another measure is cross-elasticity; it shows the sensitivity of the demand for one product relative to price changes in another product. When the cross-elasticity coefficient is positive, the two goods are substitutes; when the coefficient is negative, a complementary relationship is indicated. The closer the coefficient is to zero, the more independent are the two items.

The concept of elasticity can be also applied to supply. For example, an analysis of labour supply in Thailand (Panayotou, 1986) shows that elasticity of labour in fisheries with respect to total salary is 0.55, which means that a 10% change in salary would bring a 5.5% shift in supply of labour for fishing. However, the same change in total income of fishermen, workers, etc., would affect the fisheries labour supply by less than 1%.

It is noted that the methods of projection for market demand curves are generally based on extrapolation of historical data and a knowledge of the income-demand function, using statistical techniques for forecasting and time-series information.

The mathematical expression which simultaneously defines the influence of, and changes in, income and price, takes the special form of a Cobb-Douglas function

$$Q = K \times P^{\epsilon p} \times I^{\epsilon I}$$

where Q represents quantity demanded, P is the price index, I income *per caput*, ϵ_p the price elasticity coefficient and ϵ_I the income elasticity coefficient. A useful property of this function is to be converted in a linear function if it is rewritten as:

$$\ln Q = \ln K + \epsilon_p \times \ln P + \epsilon_I \times \ln I$$

The information provided from an estimate of future demand is invaluable for making decisions in a firm; it is a starting point to define reasonable production objectives and identify the ways and means necessary to achieve those objectives. This is not primarily an engineering function, but the achievement of sales-volume and product-price forecasts is perhaps the most important factor in determining the success of an investment.

Example A.1 Analysis of Income and Consumption. Market Outlook

Analyse the figures given in Table A.1 for crustacean consumption in Japan.

Table A.1
Yearly Expenditure by Commodities per Household by Income Group

Income Group	Shrimp, Lobster and Crab		
	Expenditure (US$)	Quantity (100 g)	Price (US$/100 g)
Average income	33.85	36.866	0.918
I. (- 9 792)	21.38	25.571	0.836
II. (9 792-12 864)	29.18	32.847	0.888
III. (12 864-16 368)	32.86	36.913	0.890
IV. (16 368-21 600)	36.67	39.573	0.972
V. (21 600-)	49.18	49.427	0.995

Answer: Income cross-section in Table A.1. shows a strong positive correlation between income and crustacean consumption. There is the obvious indication that a substantial growth in purchase and expenditure may be expected as the household income moves from group I to II and from II to III, the three of them numerically important, which suggests that rising living standards over a wide range of the Japanese populations are likely to be reflected in higher consumption of crustaceans including shrimp.

The strongly rising trends in expenditure from lower to higher income groups on this latter item suggest that the prospect for this commodity are particularly good. In order to complete the examination of the characteristics of and prospective demand for crustacean it is necessary to study the pattern of supplies, consumption on trends, price trends and distribution and marketing channels (Hotta, 1979).

Example A.2 Analysis of Wholesale Demand for Canned Sardine in Maine (USA)

Analyse the coefficient of each variable in the following equations in order to calculate the possibility of other products, such as canned sardines from the Gulf of Mexico, penetrating the US market for canned products. In the study of demand for canned sardines carried out in Maine (USA), Raizin and Regier (1986) present three equations which relate the domestic price of sardines, annual demand and price of imported sardines with the rest of the variables (all variables are expressed by their natural logarithms):

1. $PM = -6.09 + 0.03QM + 0.31PO + 0.142PNO + 0.064PS + 0.068PT + 0.97Y$
2. $QM = 9.10 + 0.25PM + 0.338PO - 0.153PNO + 0.918PT - 2.03Y$
3. $PO = 3.36 - 0.369QO - 0.066PNO + 0.184PM + 0.145PS + 0.561PT - 0.461Y$

where:

PM:	average price for Maine sardines paid by wholesalers (cents/lb)
QM:	annual *per caput* demand of Maine sardines by wholesalers (lb)
PO:	average price of imported sardines in oil, paid by wholesales (cents/lb)
QO:	annual *per caput* demand of imports in oil by wholesalers (lb)
PNO:	average price of imported sardines not packed in oil, paid by wholesalers (cents/lb)
PS:	average price of domestic salmon in oil paid by wholesalers (cents/lb)
PT:	average price of domestic tuna in oil paid by wholesalers (cents/lb)
Y:	gross income *per caput*

Answer: Equation 1 shows that quantity demanded has no significant effect on price but that income has a significantly positive effect. Moreover, the equation shows that prices are not determined by the demand of the wholesale market, that is, there is no significant relationship between changes in price and quantities demanded; that is because Maine producers are price-makers and thus influence the market price of sardines.

Equation 2 is an equation for demand, where income is preceded by a negative coefficient (-2.03), indicating that Maine sardines are an inferior product, where a 1% increase in the real income of the population will cause a 2.03% reduction in demand.

Equation 3 shows the influence of external variables on the price of imported sardines. The external variables considered, at the wholesaler level, are: consumption *per caput*, real prices of substitute goods and real available income *per caput.*

In general, the reciprocal of price flexibility with respect to quantity is equal to the true value of price elasticity of demand. Price flexibility to demand (percentage change in price caused by 1% change in demand) less than 1, implies that demand is elastic. Price flexibility to demand is (- 0.369), which implies an elasticity of demand of -2.71. This means that a 1% increase in demand will cause a reduction of 0.369% in price. The equation also expresses the relationship of substitutes for sardine in oil. Salmon and tuna are weak substitutes for imported sardines in oil. A 1% increase in the price of salmon will increase the price of imported sardines by 0.145%, while a 1% increase in the price of tuna will increase the price of imported sardines in oil by 0.561%. The flexibility of price to income is also negative. This indicates that a 1% increase in income will cause a 0.461% drop in price. A negative coefficient suggests that the product is an inferior good.

APPENDIX B
INTEREST AND ECONOMIC EQUIVALENCE

B.1 Financial Equations

B.1.1 Interest

The term "interest" is used to indicate the rent paid for the use of money. It is also used to represent the percentage earned by an investment in a productive operation. From the lender's point of view, the interest rate is the ratio between profit received and investment over a period of time, which is a contribution to the risk of loss, administrative costs and pure earnings or profit. From the borrower's point of view, the interest rate can be expressed as the ratio between the amount paid for use of the funds and quantity of funds requested. In this case, the interest to be paid must be less than the earnings expected.

B.1.2 Time value of money

As money can produce earnings at a certain rate of interest by being invested for a period of time, it is important to know that one unit of money received at some future date does not produce as much earnings as a unit of money received in the present. This relationship between interest and time gives rise to the concept of the "time value of money".

Money also has a time value, as its buying power of a dollar varies with time. During periods of inflation, the quantity of goods that can be bought with a certain amount of money decreases as the purchase date moves into the future. Although this change in the buying power of money is important, the concept of the time value of money is even more so, in that it has earning power. Any future reference to the time value of money will be restricted to this concept. Effects of inflation on the profitability of an investment are discussed in section 7.9. It is necessary to know the different methods for computing interest in order to calculate, with certainty, the actual effect of the time value of money in the comparison of alternative courses of action.

B.1.3 Simple interest

Normally, a rate of interest on a sum of money is expressed as the percentage of the sum that is paid for the use of the money during a one-year period, but it can also be quoted for different periods of time. In order to simplify the following discussion, examination of interest rates for periods other than one year will be made at the end of this Appendix (B.4.). The interest to be paid on a loan, at simple interest, is proportional to the principal sum. With P as the principal sum, n the number of years and i the interest rate, simple interest can be expressed as:

$$I = P \times n \times i \qquad \text{(B.1)}$$

A loan at simple interest can be made for any period of time. The interest and the initial sum will be paid at the end of the loan period.

Example B.1 Simple Interest

Find the simple interest on US$ 4 500 at 8% per year for a) 1 year and b) 4 years.

Answer:

(a) I = P x n x i
I = US$ 4 500 x 1 x 0.08 = US$ 360

The initial sum plus interest increases to US$ 4 860 and will be the total debt at the end of the year.

(b) I = P x n x i
I = US$ 4 500 x 4 x 0.08 = US$ 1 440

When calculating the interest owed for a part of the year, it is usual to consider the year as made up of 12 months of 30 days each, that is, 360 days.

Example B.2 Simple Interest. Period Length Less than One Year

Find the simple interest on US$ 1 000 for the period 1 February-20 April at 8% per year.

Answer:

I = P x n x i
I = 1 000 x (80 days/360 days) x 0.08
I = US$ 17.78

B.1.4 Compound interest

When interest earned during each period is added to the principal sum, as shown in Table B.1 (see Example B.3), it is said that the interest is compounded annually. The difference between simple interest and compound interest is due to the effect of capitalization. The final total amount will be higher when large sums of money, higher rates of interest or a greater number of periods are involved. Compound interest is the type of interest that is used in practice, and thus it will be used in this manual.

Table B.1
Calculation of Compound Interest

Year	Sum owed at beginning of year (A)	Interest added to debt at year end (B)	Sum owed at year end (A + B)	Sum to be paid at year end
1	1 000	1 000 x 0.08 = 80	1 080	0.00
2	1 080	1 080 x 0.08 = 86.4	1 166.4	0.00
3	1 166.4	1 166.4 x 0.08 = 93.3	1 259.7	0.00
4	1 259.7	1 259.7 x 0.08 = 100.8	1 360.5	1 360.5

To allow the visualization of each economic investment alternative a cash expenditure and receipts diagram (Figure B.1) is used. This graphic method provides all the information required to analyse an investment proposal. This diagram shows income received during the period with an upward arrow (increment of money) positioned at the end of the period (it is always assumed to take place at the end of the period in question). The length of the arrow is proportional to the size of the income received during the period. Similarly, expenditure is represented by a downward arrow (a reduction of money). These arrows are located on a time-scale that represents the duration of the alternative.

Figures B.1 (a) and (b) also show the flow diagrams for the borrower and the lender of the previous example, where the expenses incurred in initiating an alternative are deemed to have taken place at the beginning of the period over which it extends.

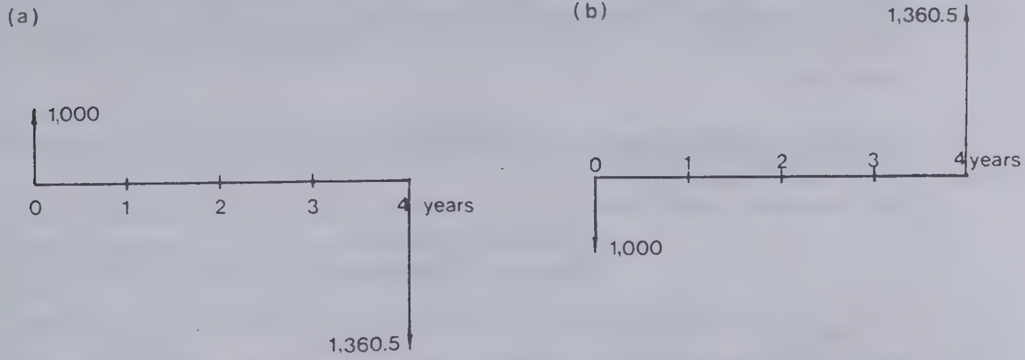

Figure B.1 Expenditure and Receipts Diagram: (a) Borrower and (b) Lender

Example B.3 Compound Interest

Find the total debt to be paid at the end of 4 years. The sum owed is US$ 1 000 at 8% per year.

Answer: Results of calculation are shown in Table B.1. and Figure B.1.

B.2 The Meaning of Equivalence

In order to evaluate investment alternatives, sums of money produced at different points in time must be compared. This is only possible if their characteristics are analysed on an equivalent basis. Two situations are equivalent when they have the same effect, the same worth or the same value. Three factors are involved in the equivalence of investment alternatives:

- the amount of money
- the time of occurrence
- the rate of interest

The factors of interest which will be developed take account of duration and rate of interest. Later, they are used in the transformation of alternatives in terms of a common time-base.

B.3 Derivation of Interest Factors

Interest factors applicable to routine situations, such as compound interest with single payment, and with a series of equal payments, will be derived. The following five points must be kept in mind for application in calculations of investment alternatives:

1. The end of one period is, at the same time, the beginning of the next period.

2. P is produced at the beginning of a period, at a time in the present;
3. F occurs at the end of the nth period, from a time considered as present (n being the total number of periods).
4. A is a single payment within a series of equal payments made at the end of each period under consideration. When P and A occur together, the first A in the series is produced one period after P. When F and A occur together, the last A in the series occurs at the same time as F. If the equal payments series occurs at the beginning of each period under consideration, it is called A_b.
5. In proposing different alternatives, the quantities P, F, A and A_b must be used such that they incorporate the conditions needed to adjust the respective models to the factors used.

Table B.2 summarizes the financial equations that show the relationships between P, F and A (Jelen and Black, 1983).

Table B.2
Financial Equations

- Single-payment compound-amount factor:

Given P, find F $F = P \times [(1 + i)^n]$ $F = P \times F_{PF, i, n}$

- Single-payment present-worth factor:

Given F, find P $P = F \times [(1 + i)^{-n}]$ $P = F \times F_{FP, i, n}$

- Equal-payment series present-worth factor:

Given A, find P $P = A \times \dfrac{(1+ i)^n - 1}{i \times (1 + i)^n}$ $P = A \times F_{AP, i, n}$

- Equal-payment series capital-recovery factor:

Given P, find A $A = P \times \dfrac{i \times (1 + i)^n}{(1 + i)^n - 1}$ $A = P \times F_{PA, i, n}$

- Equal-payment series-compound-amount factor:

Given A, find F $F = A \times \dfrac{(1 + i)^n - 1}{i}$ $F = A \times F_{AF, i, n}$
$F = A \times F_{AP, i, n} \times F_{PF, i, n}$

- Equal-payment series sinking-fund factor:

Given F, find A $A = F \times \dfrac{i}{(1 + i)^n - 1}$ $A = F \times F_{FA, i, n}$
$A = F \times F_{FP, i, n} \times F_{PA, i, n}$

B.3.1 Compound-interest factor with single payment

If a sum P is invested at the rate of interest i, how much money is accumulated between capital and interest at the end of period n; or, what is the equivalent value at the end of the final period n, of the sum P invested at the beginning of the operation? The cash flow diagram for this financial situation is shown in Figure B.2. Table B.1 shows interest earned on applying compound interest to the investment described in Figure B.2. This investment provides no income during the intermediary periods. In Table B.1, the interest earned is added to the initial sum at the end of each interest period (annual capitalization). Table B.3 shows the deduction in general terms.

Table B.3
Deduction of Compound-interest Factor with Single Payment

Year	Amount at beginning of year	Interest earned during year	Compound Interest at year end
1	P	$P \times i$	$P + P \times i = P \times (1+i)$
2	$P \times (1+i)$	$P \times (1+i) \times i$	$P \times (1+i) + P \times (1+i) \times i = P \times (1+i)^2$
3	$P \times (1+i)^2$	$P \times (1+i)^2 \times i$	$P \times (1+i)^2 + P \times (1+i)^2 \times i = P \times (1+i)^3$
n	$P \times (1+i)^{n-1}$	$P \times (1+i)^{n-1} \times i$	$P \times (1+i)^{n-1} + P \times (1+i)^{n-1} \times i = P \times (1+i)^n = F$

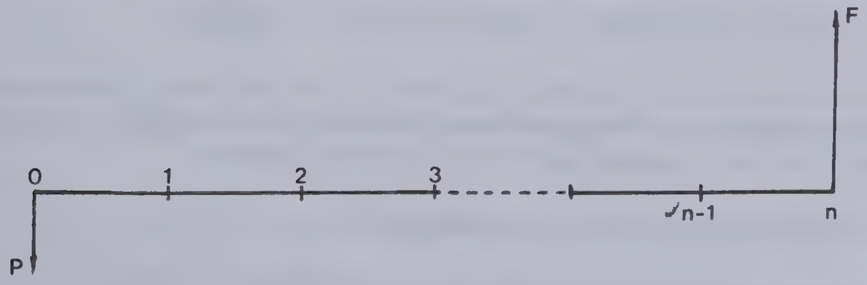

Figure B.2 Single Present Amount and Single Future Amount

The resulting factor $(1 + i)^n$ is known as the compound-interest factor with single payment, and is written F_{PF}; the relationship is:

$$F = P \times (1 + i)^n \tag{B.2}$$
$$F = P \times F_{PF} \tag{B.3}$$

Example B.4 Single-payment Compound-amount Factor

Find the compound amount of US\$ 1 000 in 4 years at 8% interest compounded annually.

Answer: From Equation B.3,

$$F = 1\,000 \times (1 + 0.08)^4 = 1\,000 \times 1.3605 = \text{US\$ } 1\,360.5$$

Another way of interpreting Equation B.3 is that the amount F at some future time is equivalent to the known value of P at the present time, for the given interest rate of i. The amount F, US\$ 1 360.5, is equivalent to the initial amount P, US\$ 1 000 at the end of four years if the interest rate is 8% per year.

B.3.2 Present-worth factor with single payment

Solving P from the last Equation B.2 results in:

$$P = F \times \frac{1}{(1 + i)^n} \qquad \text{(B.4)}$$

The resulting factor $(1 + i)^{-n}$ is known as the present-worth factor with single payment and is written as F_{FP}:

$$P = F \times F_{FP} \qquad \text{(B.5)}$$

Example B.5 Single-payment Present-worth Factor

How much should be invested now (at present time) at 8% compound interest per year, in order to receive US$ 1 360.5 within 4 years; or what is the present equivalent worth of US$ 1 360.5 to be received four years in the future?

Answer: From Equation B.5,

$$P = 1\,360.5 \times (1/1.3605) = 1\,360.5 \times 0.73503 = \text{US\$ } 1\,000$$

It is noted that the two factors are reciprocal. In the Net Present Value and Internal Rate of Return methods used to evaluate the profitability of projects (Chapter 7), the present-worth factor is applied to compare cash flows with initial investment.

B.3.3 Compound-interest factor with equal-payment series

As an introduction, a definition will be given of the concept of annuity, which consists of a series of equal payments made at regular intervals of time, whether annually or at different periods. This scheme arises in situations such as accumulation of a determined capital (receipt of a certain lump sum after a certain amount of periodic payments, as occurs in some life insurance plans), or cancellation of a debt. Figure B.3 shows the first situation, given that the future value is being sought, through a series of equal payments made at the end of successive interest periods.

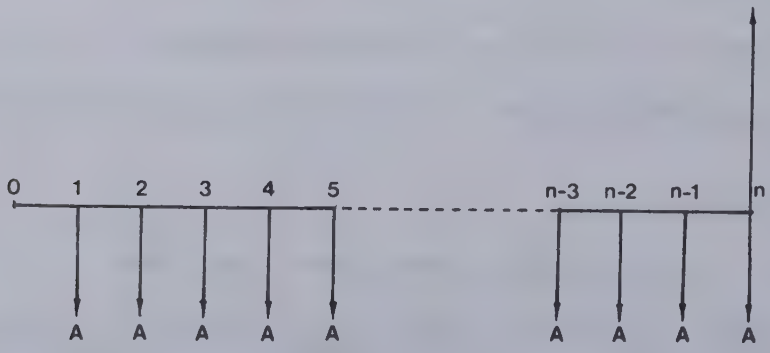

Figure B.3 Single Future Amount with Equal-payment Series

The sum of the compound interest of the different payments can be calculated through the use of the compound-interest factor with equal payment series. The method of calculating the factor is to use the compound-interest with single payment factor to transform each A into its future value:

$$F = A + A \times (1+i) + A \times (1+i)^2 + A \times (1+i)^3 + \ldots + A \times (1+i)^{n-1} \qquad (B.6)$$

This is a geometric ratio series (1+i)

$$F = A \times [1+(1+i) + (1+i)^2 + (1+i)^3 + \ldots + (1+i)^{n-1}] \qquad (B.7)$$

The sum of a geometric series is equal to:

$$\frac{1 - (\text{ratio})^{\text{Number of terms}}}{1 - \text{ratio}} \times (\text{first term}) \qquad (B.8)$$

In this case:

$$F = A \times \frac{1 - (1+i)^n}{1 - (1+i)} \times 1 \qquad (B.9)$$

$$F = A \times \frac{(1+i)^n - 1}{i} \qquad (B.10)$$

The resulting factor $[(1+i)^n - 1]/i$ is known as the compound interest factor with equal payment series and is written as F_{AF}:

$$F = A \times F_{AF} \qquad (B.11)$$

Example B.6 Equal-payment Series Compound-amount Factor

Find the amount compounded for a series of five payments of US$ 500 made at the end of each year at 8% per year.

Answer: Calculation is illustrated in Table B.4.

From Equation B.11:

$F = 500 \times [(1.08)^5 - 1]/0.08 = 500 \times 5.8664$

F = US$ 2 933.2

That is, the amount of US$ 2 933.2 at the end of the five periods is equivalent to five annual payments of US$ 500, when the rate of interest is 8% per period.

Table B.4
Example of Compound-interest Factor with Equal-payment Series

Year end	Compound-Interest Factor with year end payments	Compound Interest at end of 5 years	Total Compound Interest
1	$500\ (1.08)^4$	680.2	
2	$500\ (1.08)^3$	629.8	
3	$500\ (1.08)^2$	583.2	
4	500 (1.08)	540.0	
5	500	500.0	2 933.2

B.3.4 Sinking-fund factor with equal-payments series

Solving A from the expression (B.10) results in:

$$A = F \times \frac{i}{(1 + i)^n - 1} \tag{B.12}$$

The resulting factor $i/[(1 + i)^n - 1]$ is known as the sinking-fund factor with equal-payment series.

$$A = F \times F_{FA}$$

Example B.7 Equal-payment Series Sinking-fund Factor

One wishes to accumulate US\$ 2 933.2, through a series of five annual payments, at 8% interest per year, which is the amount required for each payment?

Answer: From Equation B.12 it will be:

$$A = 2\,933.2 \times \frac{0.08}{(1 + 0.08)^5 - 1} = \text{US\$ } 500$$

Derivation of this factor and the examples shows that the compound-interest factor with equal-payment series and the sinking-fund factor with equal-payment series are reciprocal.

B.3.5 Capital-recovery factor with equal-payment series

Amount P is deposited at a present time, at an interest rate of i per year. The depositor wishes to withdraw the capital plus the interest earned in a series of equal year end receipts over the next n years. When the last withdrawal is made, no funds remain in the deposit. Moreover, it can be said that whatever the uniform payment is at the end of each period, it is equivalent to the amount invested at the beginning of the first year. The cash flow diagram is shown in Figure B.4. To calculate this factor, it should be expressed as the product of two factors which are already known, compound-interest factor with single-payment ($F_{PF}^{i,\,n}$) and the sinking-fund factor with equal-payment series ($F_{FA}^{i,\,n}$).

$$A = P \times F_{PA} = P \times F_{PF} \times F_{FA} \tag{B.13}$$

$$A = P \times (1+i)^n \times \frac{i}{(1+i)^n - 1} \tag{B.14}$$

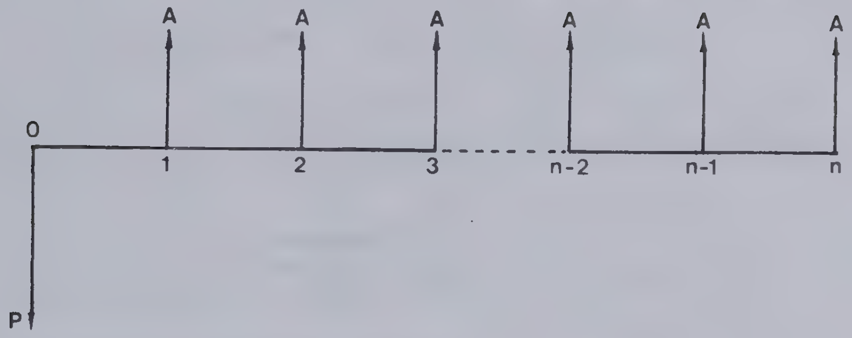

Figure B.4 Single Present Amount and Equal-payment Series

$$A = P \times \frac{i \times (1+i)^n}{(1+i)^n - 1} \tag{B.15}$$

The resulting factor $i \times (1+i)^n / [(1+i)^n - 1]$ is known as the capital-recovery factor with equal-payment series, and is written as $(F_{FA}{}^{i,\,n})$. It is used to calculate equal payments required to amortize a present amount of a loan, where the interest is calculated on the balance. This type of financial settlement is the basis of the majority of loans and constitutes the most common form of amortizing a debt.

B.3.6 Geometric series

In many cases, the annual payments are not made in an equal-payment series. In some countries it is common to find geometric series of payments, that is, payments where each term is equal to the previous one, multiplied by a factor:

$$S + \alpha \times S + \alpha^2 \times S + \alpha^3 \times S + \ldots + \alpha^{n-1} \times S \tag{B.16}$$

where S stands for the first payment and r, the factor by which it is multiplied. This series can symbolize, for example, a monthly indexed quota, with a monthly interest of α. In this case, the initial quota is S. To be able to work with this series through the known formulas, each of the quotas should first be brought to present values:

$$P = \frac{S}{1+i} + \frac{\alpha \times S}{(1+i)^2} + \frac{\alpha^2 \times S}{(1+i)^3} + \frac{\alpha^3 \times S}{(1+i)^4} + \,.\,.\, + \frac{\alpha^{(n-1)} \times S}{(1+i)^n} \tag{B.17}$$

After removing the common S/r factor in the series:

$$P = \frac{S}{\alpha} \times \left[\frac{\alpha}{1+i} + \frac{\alpha^2}{(1+i)^2} + \frac{\alpha^3}{(1+i)^3} + \frac{\alpha^4}{(1+i)^4} + .. + \frac{\alpha^n}{(1+i)^n} \right] \tag{B.18}$$

the expression between parentheses is the sum of the geometric ratio series $\alpha/(1+i)$

$$P = \frac{S}{\alpha} \times \frac{1 - \left(\frac{\alpha}{1+i}\right)^n}{1 - \frac{\alpha}{1+i}} \times \frac{\alpha}{1+i} \qquad \text{(B.19)}$$

Working with this expression it is possible to obtain:

$$P = \frac{S}{\alpha} \times \frac{(1+i)^n - \alpha^n}{(1+i) - \alpha} \times \frac{(1+i)}{(1+i)^n} \times \frac{\alpha}{(1+i)}$$

$$P = S \times \frac{(1+i)^n - \alpha^n}{(1+i) - \alpha} \times \frac{1}{(1+i)^n} \qquad \text{(B.20)}$$

If instead of working with present value, the annual quotas equivalent to the series are required, the following equations should be used:

$$A = P \times F_{PA} = S \times \frac{(1+i)^n - \alpha^n}{(1+i) - \alpha} \times \frac{1}{(1+i)^n} \times \frac{i(1+i)^n}{(1+i)^n - 1}$$

$$A = S \times \frac{(1+i)^n - \alpha^n}{(1+i) - \alpha} \times \frac{i}{(1+i)^n - 1} \qquad \text{(B.21)}$$

In this way, whether using P or A, it is possible to work easily with the known equations.

B.4 Nominal and Effective Rates of Interest

To simplify matters, the discussion of interest has been based on interest periods of one year. However, agreements may specify that interest be paid more frequently, for example, biannually, quarterly, or monthly. Such agreements result in interest periods of six months, three months or one month, and the interest is compounded twice, four times or twelve times for the year, respectively.

The interest rates associated with this method of more frequent compounding are normally quoted on an annual basis according to the following convention. When the effective rate of interest is 4.8% compounded every 6 months, the annual or nominal interest is quoted as "9.6% annually, compounded biannually". For a 2.4% effective rate of interest compounded at the end of each 3-month period, the nominal interest is quoted as "9.6% annually, compounded quarterly". Thus the nominal rate of interest is expressed on an annual basis and this is determined by multiplying the effective rate of interest by the number of interest periods in the year.

B.4.1 Discrete compound rate of interest

The effect of compounding more frequently is that the effective rate of interest, is higher than the nominal rate of interest. For example, consider a 9.6% nominal rate of interest, compounded biannually. The value of a dollar at the end of a year, when a dollar is compounded at 4.8% for each 6-month period is:

$$F = \text{US\$ } 1(1.048)\ (1.048) = \text{US\$ } 1\ (1.048)^2 = \text{US\$ } 1.0983$$

The real interest earned on the dollar for a year, is equal to US$ 0.0983. As a result, the effective rate of interest is 9.83%. An expression for the annual effective rate of interest can be derived from the last reasoning, that is:

i = nominal rate of interest (annual)
i_{eff} = effective rate of interest (per period)
c = number of interest periods per year

$$i_{eff} = \text{annual effective rate of interest} = (1 + i/c)^c - 1 \qquad \text{(B.22)}$$

Example B.8 Effective Rate of Interest

Find the value of US$ 1 000 for 4 years at a 10% nominal rate compounded quarterly.

Answer: From Equation B.22,

$$i_{eff} = (1 + 0.10/3)^3 - 1$$

$$i_{eff} = 10.33\%$$

Using Equation B.3

$$F = P \times F_{PF}^{10.33\%,4\ \text{years}} = 1\ 000 \times (1 + 0.1033)$$

$$F = \text{US\$ } 1\ 482$$

B.4.2 Continuous compound rate of interest

As a limit, interest can be considered to be compounded an infinite number of times per year, that is continually. Under these conditions, continual annual effective interest for interest compounded continuously is defined as:

$$i_{eff} = \lim_{c \to \infty} (1 + i/c)^c - 1 \qquad \text{(B.23)}$$

The right side of the equality is rearranged to include i in the exponent:

$$(1 + i/c)^c = (1 + i/c)^{i \times c/i} \qquad \text{(B.24)}$$

The value of the mathematical symbol e is the value of $(1 + 1/n)^n$ as n approaches infinity, then:

$$\lim_{c \to \infty} (1 + i/c)^{c/i} = e \qquad \text{(B.25)}$$

By substitution,

$$i_{eff} = \lim_{c \to \infty} (1 + i/c)^{i \times c/i} - 1 = e^i - 1 \qquad \text{(B.26)}$$

As a result, when interest is compounded continuously,

$$i_{eff} = \text{annual effective rate of interest} = e^i - 1 \qquad \text{(B.27)}$$

B.4.3 Comparison of interest rates

The effective rates of interest which correspond to a 9.6% nominal rate, compounded annually, biannually, quarterly, monthly, weekly, daily and continuously, are shown in Table B.5.

Table B.5
Comparison of Interest Rates

Frequency of Compounding	Number of Periods Per Year (c)	Effective Interest Rate Per Period (i_p)	Annual Effective Interest Rate (i_{eff})
Annually	1	9.6%	9.60% (*)
Biannually	2	4.8%	9.83%
Quarterly	4	2.4%	9.95%
Monthly	12	0.8%	10.03%
Weekly	52	0.1846%	10.06%
Daily	365	0.0263%	10.074%
Continuously	$c \to \infty$	$i_p \to 0$ %	10.076%

Note:

* The annual effective rate of interest always equals the nominal rate when interest is compounded annually.

Since the effective interest rate represents the real interest earned, it is this rate which must be used to compare the benefits of various nominal rates of interest.

B.5 Inflation and Interest

The behaviour of the world economy in the past shows a general inflationary tendency in the cost of goods. This tendency was reversed during specific periods, but from a global point of view there seems to be an incessant pressure on prices to increase. Low inflation rates seem to have little impact on changes in prices, but when inflation exceeds 10%

annually, it can produce extremely serious consequences for individuals and for institutions (see section 7.9).

Inflation is normally described in terms of an annual or monthly percentage, which represents the rate at which prices of goods in the year or month being considered increased in relation to the prices of the previous year or month. Since the rate is defined in this manner, inflation has a compounded effect. Therefore, prices which inflate at a rate of 8% monthly will increase by 8% in the first month and in the following month the expected increase will be 8% of the new prices. Since the new prices include the original 8% increase, the rate of increase is applied to the 8% increase already added.

The same applies to the successive months and as a consequence, the inflation rates are compounded in the same manner as the interest rate. To incorporate the effects of inflation in economic studies, interest factors must be used such that inflationary effects can be identified in monetary values at the different points in time. The standard procedure to avoid the loss of buying power that accompanies inflation is:

1. Study all costs associated with a project in terms of present monetary value.
2. Modify the costs estimated in step 1 so that at each future date they represent the cost at that time in terms of the monetary values that must then be spent.
3. Calculate the equivalent quantity of cash flow which results from step 2, considering the time value of money (interest rate of the market).

It is important to observe that the interest rate at which it is possible to invest in a financial or banking operation represents the market interest rate (financial standard). This interest rate is compounded by the inflation rate and the opportunity of earning. If these two effects are separated; i_R, the rate which represents the money's earning power without inflation, is related to i, the market rate and ß, the inflation rate, by Equation 7.25 of this manual as:

$$(1+i) = (1+\beta) \times (1+i_R)$$

$$i_R = \frac{1+i}{1+\beta} - 1 \qquad \text{(B.28)}$$

Example B.9 Real Rate of Interest

A person invests his money in a bank at an interest rate of 25% per year where the inflation rate is 20% per year. What is the true or real interest rate?

Answer: From Equation B.28

$$1+i_R = (1+0.25)/(1+0.20) = 1.042$$
$$i_R = 4.2\%$$

This example shows that the effect of the inflation is to make a business seems more profitable than it actually is.

APPENDIX C
COST DATA

C.1 Cost of Equipment and Plants

(i) Cost of Packaging Machines (Graham, 1984)

Method	Manpower	Throughput	Energy, W	Cost, US$
Heat Sealing	Manual	-	70-300	75-300
	Manual	-	500	900
	Semi-automatic	Up to 200 mm/s	900	2 000
Continuous	Semi-automatic	150-200 mm/s	1 400	7 000-10 000
Vacuum Packing				
Bag fed	Manual	15-20s cycle	550	2 700-3 200

(ii) Cost of Processing Equipment in Fish Filleting and Freezing Plants, 500 t Raw Material/Year, Uruguay (Kelsen *et al.*, 1981)

Fillet, skinned, few bones, interleaved	**US$**
TRIO skinning machine for removing fat (*)	35 000
Mechanical V cut table, 20 workers	25 000
Lighted control table, 4 workers	8 000
Mechanical fish block table, 8 workers	10 000
600 trays of 7.5 lb aluminum ea.	9 000
Weighing machine	2 500
Plastic Trays	500
TOTAL	90 000

(*) With possibility to adjust cut thickness for removing sub-cutaneous fat.

(iii) Freezing Plants, Data for a Frozen Shrimp Plant, 900 kg/day, UK (Graham, 1984)

Item	**US$**
Building; 250 m², US$ 135/m²	33 750
Plate Freezer, 180 kg/load	22 275
0°C Chilling Room, 10 t	9 900
-30°C Cold Store, 20 t	17 550
Freezer trays, 30 x 2	2 925
Fish boxes, 500	6 187
Ice plant, 2.7 t/24 h	19 800
Ice storage bin (local construction)	4 950
Standby generator, 70 kVA	13 983
Weighing machine, 100 kg flat bed	675
Work tables, 6, stainless steel top, wooden supports	4 500
Steam cleaner, with water input, Diesel powered	2 925
Production line items	4 950
Office equipment, clothing, etc.	4 950
Pick-up truck	2 375
Sub-total	151 695
10% contingency	15 169
Total	166 864
CIF at 20% items (excluding building)	23 589
10% installation and commissioning items (excluding building)	11 794
Total	202 247

(iv) Cost of Processing Equipment, Fish Protein Concentrate Plant, FPC, Type B, Senegal, 13,6 t Finished Product/day (Vaaland & Piyarat, 1982)

	US$
Installation of complete processing equipment: coagulator, press, rotadisk drier and evaporator including freight, insurance, assembly, starting-up and running in-costs	1 236 400
Laboratory equipment	43 000
Packaging machinery for 75 kg bags	27 400
Buildings	385 420
Total	1 692 220

(v) Cost of Drying Plants (Waterman, 1977)

1. Small freshwater fish, East Africa, dried in a mechanized drier or naturally by the sun (0.2 t finished product/day

Drying Method (N)	**Mechanical (M)**	**Natural**
Land (M: 500 m²; N: 1 800 m²) x US$ 1/m²	500	1 800
Storage 20 m² x US$ 75/m², 10 t capacity	1 500	1 500
Buildings for offices and processing, M: 100 m², N: 10 m² x US$ 75/m²	7 500	750
Mechanized drier, with attachments, installed	9 000	---
Drying frames, 600 m² x US$ 1.2/m²	---	720
Other equipment and incidentals expenses	1 500	1 230
	-----	-----
Total Fixed Investment	20 000	6 000

2. Simple drying/smoking. Small freshwater sardine (*Stolothrissa tanganicae*) in East Africa. The fish is first brined (10%), sun dried on frames for about 10 h and smoked in a non-mechanized smoke-house for 4 h. Maximum period of production: 220 days/year

Investment Cost	**US$**
Construction of drying and smoking plant	22 000
Equipment (scales, seamer, generator, hydraulic pump, others)	8 000

Total Investment	30 000

3. Highly mechanized drying of salted fillets in small and large scale driers.

Investment Cost	Large Drier	Small Drier
(driers only)	190 000	8 000

(vi) Investment for Artisanal Fishmeal Plants, Tanzania, 20 kg Finished Product/day (Mlay and Mkwdizu, 1982)

	US$
Cooking area, covered	17
Drying and milling	14
Storage	57
Drying materials	22
Working capital	57

Total	168

(vii) Small scale fishmeal plants, 80 kg/day (Etoh, 1982)

	US$
Equipment (heater, cooker, cooking basket, press, crusher, drier, grinder, others)	1 433.0
Miscellaneous including fittings, rakes, shovel, etc.	145.6
Total	1 578.9

(viii) Large-scale Fishmeal Plants (Atlas, 1975)

Capacity	Cost, US$ Concentration of Stickwater	
t of raw material/24 h	Without	With
15	200 000	
25	235 000	
30	320 000	
60		455 000
150		800 000
250		1 100 000

(ix) Cost of Equipment for the Fishery Industry

Equipment	Throughput	Unit	Cost, US$	Country	Reference
Steamboiler	3 500	kg/h	45 500	Norway	(Myrseth, 1985)
Compressed air plant	2 500	l/h	3 250	"	"
Can seaming machines	150	cans/min	49 400	"	"
Overpressure retort	5 500	cans of 450 g	58 500	"	"
Gutting machines	30	fish/min	22 500	UK	(Graham, 1984)
Heading machines	35	fish/min	7 500	"	"
Heading and gutting machines	180	fish/min	22 600	Argentina	1994
Battering and breading machines	350	kg/h	22 500	UK	(Graham, 1984)
Forming machine	2000	kg/h	22 500	"	"
Filleting table	1	post (0.85 m^2)	340	Argentina	1994
Whole fish washer (recycling water)	40	t/8 h	25 900	"	"

C.2 Cost of Raw Material

Raw material	US$	Unit	Country	References
Hake	230-280	t	Argentina	1990
Hake	250	t	Uruguay	(Kelsen *et al.*, 1981)
Sea Salmon	650	t	Argentina	1990
Kingclip	800	t	"	"
Croaker	580	t	Uruguay	(Kelsen *et al.*, 1981)
Anchovy	700	t	Argentina	1989
Sardine for drying/smoking	195	t	Africa	(Waterman, 1977)
Sardines	183	t	Tropical Countries	(Edwards *et al.*, 1981)
Sardines	197	t	Norway	(Myrseth, 1985)
Tuna (Yellowfin)	250	t	Indonesia	(Bromiley *et al.*, 1973)
Tuna	1000	t	Cape Verde	1990
Shrimp	361	t	Indonesia	(Bromiley, 1973)
Fish for fishmeal plants	40-50	t	Tropical Countries	(Shaw, 1976)
Fish for fishmeal	45	t	Europe	(Atlas, 1975)
Fish for fishmeal	41.7	t	Tanzania	(Mlay and Mkwizu, 1982)
Fish for fishmeal and drying	80	t	Brazil	(Vaaland & Piyarat, 1982)
Fresh water fish for fishmeal	60	t	African Countries	(Waterman, 1977)
Fish, Pacific Pollock	121	t	USA	(Bartholomai, 1987)
Fish for canning and freezing, including shellfish	160-380	t	Tropical Countries	(Shaw, 1976)
Sunflower oil	0.5	kg	Cape Verde	(1990)
Bread crumbs	0.52	kg	Argentina	1990
Medium quality salt	0.3	kg	"	"
Salt	0.5	kg	Cape Verde	(1990)
Salt	0.182	kg	African Countries	(Waterman, 1977)
Wood	1.3	m^3	"	"

C.3 Labour Rates in the Fishery Industry

Process	Labour, US$	Unit	Country	Reference
Frozen				
Filleters	0.06	kg skinless hake fillet	Argentina	1990
Labourers	1.12	hour	"	"
Packagers	1.11	hour	"	"
Freezer Attendants	1.49	hour	"	"
Salted, dried and canned				
Labourers	0.80	hour	Argentina	1990
Packagers	0.79	hour	"	"
Workers, drying	0.30	day	African Countries	(Waterman, 1977)
Workers, canning	1.35(*)	day	Indonesia	(Bromiley *et al.*, 1973)
Workers	10.00(*)	day	Cape Verde	1990
Supervisor	14.00(*)	day	"	"
Industrial Workers				
	3-4	day	Tropical Countries	(Shaw, 1976)
Untrained workers	0.78	hour	Brazil	(Vaaland & Piyarat, 1982)
Specialized workers	0.11	hour	Africa	(Waterman, 1977)
Processing workers	155.4	month	Senegal	(Jarrold & Everett, 1978)
Salaries, permanent personnel				
Administrative employee	200-300	month	Argentina	1990
Foreman	300-500	month	"	"
Production Chief	1 000	month	"	"
Managers	1 500-2 000	month	"	"
Maintenance Officials	400-600	month	"	"
Machinists	400-600	month	"	"
Managers	4 059	year	Brazil	(Vaaland & Piyarat, 1982)
Foreman	1 462	year	"	"
Manager	1 125	month	UK	(Graham, 1984)
Supervisor	560	month	"	"
Administrative	337	month	"	"
Mechanical	150	month	"	"
Workers	90	month	"	"
Administrative	333	month	Senegal	(Jarrold & Everett, 1978)
Technicians	444	month	"	"
Catching				
Captain	39	month	Bangladesh	(Eddie & Nathan, 1980)
Crew	19.5	month	"	"
Non-specialized fisherman	133.2	month	Senegal	(Jarrold & Everett, 1978)

(*) Includes social benefits

C.4 Cost of Utilities

Utility	Cost, US$	Unit	Country	Reference
Electricity				
	0.20	kWh	Argentina	1990
	0.10-0.15	kWh	Tropical Countries	(Shaw, 1976)
	0.1125	kWh	UK	(Graham, 1984)
	0.069-0.076	kWh	Tropical Countries	(Edwards, 1981; Street, 1980)
	0.044	kWh	Norway	(Myrseth, 1985)
	0.05	kWh	African Countries	(Waterman, 1977)
	0.0078	kWh	Brazil	(Vaaland & Piyarat, 1982)
	0.20	kWh	Cape Verde	1990
Self-generated				
	0.02-0.05(*)	kWh	USA	(Jelen & Black, 1983)
	0.016-0.045	kWh	"	"
Fuels				
Fuel Oil	0.20	l	Argentina	1990
	0.40	l	USA	(Bartholomai, 1987)
	0.2-0.28	l	"	(Jelen & Black, 1983)
	0.31	l	Tropical Countries	(Edwards, 1981)
	0.26	l	Norway	(Myrseth, 1985)
	0.2	kg	Cape Verde	1990
	0.235	kg	Brazil	(Vaaland & Piyarat, 1982)
	0.2	kg	African Countries	(Waterman, 1977)
	0.74	l	Seychelles	(Parker, 1989)
	0.27	l	Thailand	"
Fuel(**)	40	t	Peru	(Engstrom *et al.*, 1974)
Inboard engines	0.15	l	Senegal	(Jarrold and Everett, 1978)
Outboard engines	0.24	l	Senegal	"
Diesel Oil	0.21	l	Bangladesh	(Eddie & Natham, 1980)
	0.6	l	Indonesia	"
Gas Oil	0.23	kg	Morocco	(Haywood and Curr, 1987)
Natural Gas				
	0.26	m^3	USA	(Bartholomai, 1987)
	0.07-0.16	m^3	"	(Jelen & Black, 1983)
Water				
Processing	1	m^3	Argentina	1990
"	1	m^3	USA	(Bartholomai, 1987)
"	0.195	m^3	Norway	(Myrseth, 1985)
"	0.1	m^3	Tropical Countries	(Edwards, 1981)
"	0.066-0.26	m^3	USA	(Jelen & Black, 1983)
"	1	m^3	Cape Verde	
Freezing	0.56	m^3	UK	(Graham, 1984)
Ice	0.046	kg	Seychelles	(Parker, 1989)
Block Ice, 110-120 kg	1.95	block	Bangladesh	(Eddie & Natham, 1980)
	10.2	t	Thailand	(Haywood and Curr, 1987)
	23.92	t	Morocco	"
	0.022	kg	Paraguay	(FAO, 1991)
Flake Ice	0.035	kg	"	(FAO, 1991)
Ice (ready for sale)	0.16	kg	Tanzania	(Lupin, 1985b)
	0.017	kg	Europe	"

(*) Highly dependent upon the consumption and location.
(**) This price being weighted to include estimated costs for lubricants and greasing.

C.5 Cost of Packaging in the Fishery Industry

Packaging materials	Cost, US$	Unit	Country	References
Lithographed cans, 170 g	0.17	can	Argentina	1991
Cans, 380 g	0.16	can	"	"
Cans, 125 g	0.058	can	Venezuela	1990
Cans, 425 g	0.08	can	Tropical Countries	(Shaw, 1976)
Cans, N° 2	0.1-0.25	can	USA	(Bartholomai, 1987)
Cans, 115 g	0.06	can	Tropical Countries	(Edwards, 1981)
Cans, 180 g	0.12	can	Cape Verde	1990
Vacuum packs for frozen fish	0.075	kg prod.	France	(Jul, 1985)
Polyethylene	1.7-2.1	kg	Argentina	1990
Plastic bags	15	1 000 bags	Tropical Countries	(Shaw, 1976)
Bags for dried fish	13	1 000 bags	African Countries	(Waterman, 1977)
Nylon, interleaved	1.33	t prod.	Uruguay	(Kelsen *et al.*, 1981)
Polypropylene bags, 50 kg	0.25	bag	Argentina	1990
Bags for fishmeal	0.60	bag	Tropical Countries	(Shaw, 1976)
Bags for fishmeal	0.28	bag	Europe	(Atlas, 1975)
Packaging for dry products and fishmeal	16	ton prod.	Brazil	(Vaaland & Piyarat, 1982)
Waxed cardboard boxes, 7 kg	0.26	box	Argentina	1990
Corrugated cardboard box, 21 kg	0.46-0.50	box	Argentina	1990
Master box, 15 kg	0.48	box	Uruguay	(Kelsen *et al.*, 1981)
Boxes for cans of fish	0.27	box	Tropical Countries	(Shaw, 1976)
Boxes for dried fish	0.32	box	African Countries	(Waterman, 1977)
Cardboard boxes (x 24 cans)	0.15	box	USA	(Bartholomai, 1987)
Boxes (x 100 cans)	0.50	box	Tropical Countries	(Edwards, 1981)
Boxes (x 24 cans)	0.30	box	Cape Verde	1990
Straps and labelling	4	t FB	Argentina	1990
Plastic drums, 200 kg	25	drum	Argentina	1994

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This manual analyses the microeconomics of the fish processing industry. It is mainly aimed at fish technologists, extensionists and managers and owners of small- and medium-scale fish industries, particularly in developing countries. The main topics discussed are: production engineering, capital investment costs, production costs, microeconomic analysis of production, analysis and selection of alternatives, profitability and quality and safety economics. Procedures and techniques included in the manual can be applied to analyse the feasibility of new investments, the performance of existing fish processing plants and process modifications. The publication contains a large number of examples and case-studies. Although it adopts a classical approach, it shows how this can be integrated with the proper management of resources and the production of safe and quality fish products. The need for proper management of resources such as energy and water and the impact of environmental concerns are also discussed. The document is primarily intended as a training manual; however, it is expected that it could contribute to the self-sustainability of the fishery industry in developing countries at a time when development can hardly be sought in the expansion of fish catches, but must rather be sought in the wise management of all existing resources.

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